HISTORY OF THE GREAT WAR

BASED ON OFFICIAL DOCUMENTS

MEDICAL SERVICES
HYGIENE OF THE WAR

VOL. I

EDITED BY

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PREFACE.

THE subjects dealt with in the two volumes on the Hygiene of the War represent the practical measures which were adopted for the prevention of disease.

It is difficult to estimate with any degree of accuracy the lives and man-power saved by these measures, but when the incidence of such diseases as enteric fever and dysentery in previous wars is examined, the value of practical sanitation in its direction, organization and execution is amply demonstrated, more especially on the Western front.

In the British troops during the South African War, for example, with an average strength of 208,000 and an aggregate personnel of 530,000, no less than 58,000 suffered from typhoid fever and over 8,000 died of the disease; whereas in the war of 1914–18, with an average strength of 1¼ millions and an aggregate of three or four times that number, the recorded cases of typhoid and paratyphoid fevers on the Western front for British and Dominion troops were less than 7,500, with 266 deaths only. Consequently not only was there in respect of these diseases alone an immense saving of lives and suffering but also of hospital accommodation and of personnel and material of medical services.

The records of dysentery are equally instructive. In the South African War the admission-rate for this disease was 86 per 1,000 of strength. On the Western front it never exceeded 6·18 in any year.

Apart from the prophylactic vaccines, which played so important a part in the prevention of these and other diseases but which belong more to the domain of bacteriology and pathology than hygiene, the two main directions in which sanitation helped in achieving these results were in the purification of water supplies and in the sanitary disposal of waste products, with which problems connected with the prevention of pollution of soil are closely associated. Clarification and chlorination of water supplies were measures which were constantly and assiduously carried out in practically all theatres of war from the earliest days. The details of the methods employed are recorded somewhat fully in these volumes, as in no previous campaign were such extensive and thorough measures practised. In fact, the most polluted waters, such as those of the canals

in France and Belgium, were rendered harmless and potable by the devices evolved during the war for filtration and sterilization.

In connection with the question of water supplies, Dr. W. F. Hume, the Director of the Geological Survey of Egypt, investigated from a geological point of view the localities where potable water was most likely to be obtained by borings in the areas over which the British forces advanced from Egypt into Palestine. His reconnaissances of the water supplies in North Sinai and the Wadi el Ghuzzee near Gaza are of special interest and are included in the chapters on Water Supply, as they indicate the important assistance which the geologist can render to the sanitary as well as to the engineering services of a force operating in a country more or less destitute of water.

The problem of disposal of waste products was mainly solved by incineration. Various simple and improvised methods, which proved in practice as efficient in the field as the more elaborate and expensive apparatus, were used. They had the great advantage of being capable of construction anywhere and were therefore eminently suitable in mobile warfare. There were places, however, where incineration could not be used, and the necessity of disposing of waste products by burial led to much ingenuity in the construction of pits, such as would meet the important sanitary requirement of preventing flies breeding in or having access to the waste products. All these measures are detailed in the chapter dealing with this subject.

But the war brought into prominence many other fields for sanitary action. The disinfestation of persons and clothing was the routine practice in divisions in the field from a very early period, and as the war went on the means for giving effect to these measures were gradually extended and elaborated. The work of disinfestation was also greatly stimulated amongst all ranks when the body louse was definitely demonstrated early in 1918 to be the conveyor of trench fever which had been the cause of much inefficiency. This insect was known before the war to be the transmitter of typhus fever and its influence in causing epidemics was fully understood. The results of the investigations into the cause of trench fever consequently did not involve fresh measures of sanitation, but they provided an additional stimulus to the efforts already made for disinfesting the clothing and persons of the troops.

The problem of the soldier's ration was closely allied to his work in the field and to his clothing and equipment. The energy value of the ration consequently received much and

anxious consideration, especially during the difficult period of food shortage. A complete research on the work of the soldier was carried out by Professor E. P. Cathcart, F.R.S., which enabled an estimate to be made of the minimum food requirements of the soldier. Complementary to Professor Cathcart's research was an analysis of all the common foodstuffs by Dr. Plimmer. His figures were considered to give more accurate values for the actual food consumed by the British soldier and were consequently substituted for those of Atwater and Bryant which had been previously used.

Researches were carried out in many other directions, notably on food deficiency diseases, and on the prevention and control of infective diseases. Most of the chapters in the second volume deal with these.

In connection with disease prevention, mobile hygiene and bacteriological laboratories were extensively used in the field. They were new institutions and proved of great value and assistance, not only for purposes of research but also for the recognition at the earliest possible moment of the presence of infective organisms. The mobile hygiene laboratories were also valuable in testing the care with which water supplies were being sterilized by individual units. Their work was amplified on the Western front by a base hygiene laboratory at Boulogne. The investigations, which this laboratory was called upon to carry out, are recorded in Chapter VII of the second volume and are of much general interest.

Another laboratory of a somewhat unique character in war was the physical test station in Edinburgh, an account of which is given in Chapter VI of the second volume. The investigations carried out in it had an important bearing on the work and equipment of the soldier.

In the construction of hospitals and huts, and in the measures for the provision of potable water supplies, as well as in connection with many other problems in hygiene, the medical services owed much to the ready and able manner in which the engineer services co-operated with them. In this respect the Director-General of the Army Medical Service and his staff were in constant touch from the commencement of the war with the Director of Fortifications and Works, and similar relations were maintained between the administrative and executive officers of both services in the theatres of war. Without this collaboration it would not have been possible to give effect to the sanitary measures which were considered essential for the maintenance of the health of the troops. The

chapters on housing of the soldier, the hygiene of transports, and water supplies bear specially on the combined work of both services.

But prevention of disease in the field involved more than administrative and executive control or the provision of suitable constructions and water supplies. It called for individual effort and care on the part of each officer and man, and determination on the part of the higher and subordinate commands to enforce sanitary discipline. It was, in fact, the influence of the individual probably more than of the system which was responsible for the maintenance of a high standard of health and the resulting high standard of efficiency amongst the British troops. That this influence pervaded the expeditionary forces during the war is in a great measure due to the efforts made by the numerous schools of sanitation which were established in various theatres of war and commands, as well as to the instruction which had been carried out previous to 1914. An account of these schools of instruction is given in Chapter II of the first volume.

It has been customary to compare the inefficiency and deaths from disease during a campaign with the battle casualties, and to estimate the healthiness or otherwise of the troops from the ratio of deaths from disease to deaths from wounds. Such a method of estimating the health of a force is illogical and fallacious. It can have no significance, for the ratio depends chiefly on the number and extent of the battles. A campaign such as that on the Western front with its unparalleled battle casualties would show a very high ratio of deaths from wounds as compared with deaths from disease, whereas in campaigns with few battle casualties the ratio might well be reversed without any difference in the incidence of disease. The true indicator must therefore be found elsewhere. Fortunately such an indicator had been formulated before the war and was of great assistance to the administrative medical services.

An empirical figure of 0·3 per cent. of strength had been accepted as the permissible limit of inefficiency due to sickness in an army in the field. An admission-rate exceeding this was a danger signal and indicated the presence of some preventable cause of disease, or the onset of an epidemic. Consequently when the daily admissions to field medical units for sickness were materially higher than 0·3 in any unit or division, it was generally found that some important sanitary measure had been neglected. It was remarkable how sensitive was the reaction of this means of indicating the sanitary conditions of units in the field. Divisions on first arriving from home generally

showed a daily admission-rate for sickness much higher than 0·3 per cent. of strength, sometimes as high as 1·0 per cent. But when they were taken in hand by administrative medical and sanitary officers and became better acquainted with the necessity of enforcing sanitary measures, the percentage of inefficiency dropped to well below the limit of 0·3, so much so that it was rare to find divisions with a higher rate than 0·3 per cent. During the winter months on the Western front, when measures for preventing trench foot were rigidly enforced, it was usual to find in divisions showing a higher rate of daily inefficiency than 0·3 per cent. of strength one or more regimental units which in some respect or other were not carrying out or were unable to carry out the instructions on the subject. In this way the value of the 0·3 indicator was of great assistance in having sanitary measures more strictly attended to by individual units. It is, however, a great tribute to the interest which commanding officers of regimental units and higher commands took in sanitation, that the percentage of daily admissions for sickness rarely reached even the permissible limit throughout the armies in the field, at any rate in France and Belgium. In Macedonia unfortunately sanitary measures were unable to prevent the extensive outbreak of malaria which decimated the forces there. So long as the troops were camped within the perimeter round Salonika, the sick-rate of the divisions seldom reached the 0·3 limit of daily admissions; but when military strategy necessitated the occupation of the Struma Valley, which was known to be probably the most dangerous malaria area in Europe, and when the prophylactic value of quinine failed, the admission-rate rose, and the only practical means of preventing the disease was to protect each individual soldier from being bitten by mosquitoes, or to withdraw the troops to a less malarial zone. The difficulties connected with this problem are detailed in Chapter VIII of the second volume.

In Gallipoli the massing of troops on a small promontory presented conditions, the sanitary aspects of which did not appear to have been fully realized before the expeditionary force landed. Similar conditions prevailed at first in connection with operations in Mesopotamia and East Africa, and the results of insufficient experience in meeting the difficulties which arose soon became apparent in these theatres of war. When this was recognized, advisory sanitary committees were sent out to Gallipoli, Mesopotamia and East Africa by the War Office. Parliamentary commissions, appointed to inquire into the operations of war, also referred in their reports to defects in

sanitation. As a contrast the careful arrangements made in advance for the operations in South-West Africa and North Russia resulted in an exceptionally high standard of health and efficiency, in every respect comparable to the results on the Western front. A factor which raised the admission-rate beyond the normal limit was an advance into enemy positions, where grave insanitary conditions existed in the midst of which the advancing troops were obliged to bivouac before the areas could be cleaned up. This was specially noticeable in Mesopotamia.

An account of the sanitary organization in the United Kingdom is published in the first volume of the General History of the Medical Services. Consequently the chapter on sanitary organization in the first volume of the Hygiene of the War deals only with sanitary organization in the theatres of war; but throughout the chapters in these volumes details of sanitary measures both in the United Kingdom and overseas are recorded.

In selecting subjects for these two volumes it has not been possible to avoid a certain amount of overlapping of the subjects dealt with in other volumes of the history of the medical services. But the history of hygiene during the war would have been incomplete without a record of the measures taken for the prevention of specific diseases, even although some account of these measures had been recorded in other volumes. On the other hand, the chapters on the prevention of bilharziasis, plague and smallpox compensate to some extent for the omission of these diseases from the volumes on the diseases of the war.

In the sections dealing with water supplies, no special reference has been made to the water supply in connection with operations in Gallipoli as these supplies were mainly obtained by condensing and by bringing water from Egypt. There were, it is true, a few wells both in Mudros and in Gallipoli, but these were of very little value and were scarcely used.

Acknowledgments are due to the *Journal of the Royal Army Medical Corps*, the Institution of Mechanical Engineers, the Wellcome Bureau of Scientific Research, the Tropical Diseases Bureau, the Cambridge University Press, Professor R. T. Leiper, and Messrs. J. and A. Churchill for permission to use the blocks of several of the illustrations which are reproduced in these volumes.

13th June, 1922. W. G. M.

ABBREVIATIONS.

A.D.M.S.	Assistant Director of Medical Services.
A.S.C.	Army Service Corps.
B.E.F.	British Expeditionary Force.
C.R.E.	Chief Royal Engineer.
D.A.D.M.S.	Deputy Assistant Director of Medical Services.
D.D.M.S.	Deputy Director of Medical Services.
D.G.M.S.	Director-General of Medical Services.
D.M.S.	Director of Medical Services.
E.P.	European Pattern.
G.H.Q.	General Headquarters.
I.M.S.	Indian Medical Service.
M.T.	Mechanical Transport.
N.C.O.	Non-commissioned Officer.
O.C.	Officer Commanding.
Q.M.	Quartermaster.
R.A.F.	Royal Air Force.
R.A.M.C.	Royal Army Medical Corps.
R.A.S.C.	Royal Army Service Corps.
R.E.	Royal Engineers.
T.F.	Territorial Force.
V.A.D.	Voluntary Aid Detachment.
W.A.A.C.	Women's Army Auxiliary Corps.

CHAPTER I.

SANITARY ORGANIZATION IN THE FIELD.

THE sanitary organization of the Expeditionary Force which landed in France in August 1914 was the outcome of experience gained in former wars, and was considered then to be sufficient in all respects to meet the requirements of an army in the field. But however perfect a system may appear to be at the time it is introduced, every war necessarily leads to innovations, variations or modifications, the nature of which it is impossible to forecast. A scheme which would be suitable in all climates cannot well be organized, but a sufficiently sound basis may be established to allow of expansion in matters of personnel and transport, without altering materially the general scheme or upsetting the relationship of sanitary organization to other branches of the service.

The sanitary organization of the Expeditionary Force was in this respect highly efficient. It was at the time apparently sufficient in personnel and was, in fact, the basis on which a hygiene and sanitary branch of the army was eventually constructed. In addition to the trained sanitary personnel, practically every man of the Expeditionary Force had had some training in sanitation. The principles of hygiene and sanitation in the field had been firmly established and their value fully recognized. Consequently, even during the difficulties of the retreat from Mons, efforts in sanitation were always evident in the British bivouacs. The whole fabric of the sanitary service, which was eventually developed, was more or less merely an expansion of the sanitary organization which contributed to the health of the British Expeditionary Force from the very earliest days of the war.

The officers of all units had acquired a sound knowledge of the hygiene of the march; of the necessity for supervising the personal cleanliness of the soldier and the care of his quarters and surroundings. The application of this knowledge was a matter of discipline, but presented no insurmountable difficulties with the well-trained men under their command. There were, naturally, difficulties in establishing sanitary organization and effort under trying conditions; but these were overcome to a great extent by the training of the troops previous to the war, and by the initiative of the sanitary officers and the men under

their control. Owing to the training which the officers, non-commissioned officers and men of the regular army had already received at the Army School of Sanitation in Aldershot and elsewhere, the value of the sanitary personnel in the field was recognized at once. Thus, it may be said that the nucleus of sanitary organization which existed at the commencement of hostilities was based on sound lines, and was capable of expansion under trying and novel conditions. The new developments which were subsequently of daily occurrence could have been successfully met only by a sanitary service, the organization of which had been thoroughly considered and worked efficiently.

It was evident, however, from former experience that even uniform efforts throughout a force in the field did not yield results of equal value. With mobile troops in the actual fighting line, unavoidably exposed to conditions of extreme hardship, exposure and irregular diet, sanitary efforts were bound to fail in showing results proportionate to their extent. There was always a zone of shell fire where sanitary measures were almost impossible, but immediately behind this zone sanitary measures were imperative, and there the resources and energy of the sanitary personnel were applied to the utmost degree in the prevention of ground pollution. Latrines had to be constructed with rapidity, and measures for the immediate disposal of refuse determined. There was always a tendency after an action for units to relax sanitary discipline, with the result that the fouling of the ground was to a large extent inevitable. In warm weather this readily attracted flies, and outbreaks of diarrhœa or dysentery were then to be expected. It was in these circumstances that a new development in the provision of sanitary sections to divisions was included in the organization of sanitary services.

Subsequently, the work of these sections during active offensive operations proved of immense value. The operations leading to the capture of Vimy Ridge, in April 1917, provided a good illustration of the rapidity and thoroughness with which they cleared up a battle zone. Approximately three army corps had been massed on the ground facing the Vimy Ridge, with resulting great congestion and special difficulties in maintaining a high standard of sanitation. Yet within a week after the ridge had been won, the sanitary section of the area had performed its work so efficiently that, from a sanitary point of view, it would have been difficult to believe that a number of troops had ever occupied the ground. An important result

was that the troops in this area, in contrast with those in the Somme battlefields, remained practically free from dysentery or allied disorders.

In the case of the stationary units in army areas and on the lines of communication it was expected that sanitary effort would be successful in preventing disease. It was of the utmost importance that troops should be sent from the base depôts to the front in a fit condition and free from disease. There was always a constant stream of troops passing in both directions, and there was always the danger of importation of disease by men arriving from the East and other theatres of war; hence, constant and unremitting sanitary work had always to be maintained. Sanitary organization and administration were constantly arranged so as to exclude from the base depôts men suffering from contagious or infectious disease, and at the same time keep free from disease all men passing through the various channels and fixed establishments on the lines of communication. The results in France were extraordinarily good, for with the exception of an outbreak of dysentery at one training centre, which was clearly traced to an influx of carriers from the East, and the importation of measles, mumps, and influenza, the lines of communication during the whole period of the war were maintained almost free from outbreaks of epidemic disease of any serious or extensive nature.

With the rapid increase of the army it was impossible to include the teaching of field hygiene in the intensive course of training which the troops received in the United Kingdom and at overseas bases. It was quickly realized, however, that a considerable amount of training in military hygiene and sanitation for officers, non-commissioned officers and men, was possible in the front areas, and under the direction of the Directors of Medical Services, schools of instruction were formed in every army, and also in many of the corps. At the same time medical officers of the new army were trained in practical field sanitation at schools of sanitation, both in the United Kingdom and in the various theatres of war.

The schools for instruction in sanitation in the field proved an unqualified success, and the training, such as was possible in the circumstances, soon produced results and assisted materially in maintaining the health of the troops.

The training of the special sanitary personnel during the war was carried out chiefly in the United Kingdom. Most of the personnel of the sanitary sections came from the London Sanitary Companies of the Territorial Force, R.A.M.C., or in the case of

some of the territorial divisions, by special enlistment in the division. The London Sanitary Companies were, to a great extent, responsible for the instruction which was given in the United Kingdom. Owing to the nature of the work it was important that the personnel of sanitary sections should consist of men capable of receiving and imparting information on sanitary matters, and the attributes of tact, common sense and firmness were essential.

The personnel of sanitary sections with these qualifications included engineers, sanitary inspectors, chemists, schoolmasters and men from all ranks of life. The officers were preferentially medical officers of health, or officers holding the Diploma of Public Health, but in addition there were other keen and highly trained officers who, while holding no medical degrees, were yet experts in sanitary engineering, or some similar profession. Towards the end of the war, when medical officers were scarce, these non-medical officers commanded the majority of the sanitary sections.

The sanitary organization of the army was based on the principle that the commander of every unit and formation was responsible for the sanitary condition of the quarters or localities occupied by his command, and for taking all measures necessary for the preservation of the health of those under him.

The Director of Medical Services was the responsible adviser of the Commander-in-Chief on all medical and sanitary matters, and his representatives were similarly the advisers of the commanders to whose headquarters they were attached. For each unit a regimental personnel for sanitary duties was provided, consisting of one non-commissioned officer and from two to eight men, according to the strength of the unit; in addition, one corporal, and from two to four specially trained men of the R.A.M.C. were attached for water duties. Owing to the difficulties of procuring sufficient R.A.M.C. personnel during the later stages of the war, men of the unit were substituted for the R.A.M.C. and were specially trained in water duties.

Sanitary sections were allotted to each base, and sanitary squads to each railhead and to the advanced base. A sanitary squad was also allotted to each permanent post on the lines of communication. Sanitary sections were capable of being subdivided into squads, or were increased by additional sanitary squads as required.

The personnel of a sanitary section consisted of one officer of captain's or subaltern's rank, two staff-sergeants or sergeants, and twenty-three rank and file, while that of a sanitary squad

was one sergeant and five rank and file.* In addition, the formation of a sanitary committee was authorized, consisting of a senior combatant officer as President, and two or three selected medical experts, military or civil, as members, the object of this committee being to assist general officers and the medical service in their efforts to maintain the health of the army.

At the commencement of the war there were mobilized with the Expeditionary Force in France an Assistant Director of Medical Services for sanitary services on the staff of the Director of Medical Services, a Deputy Assistant Director of Medical Services on the staff of the Deputy Director of Medical Services of the lines of communication, a specialist sanitary officer for each of the three bases, two sanitary sections and eleven sanitary squads, making a total of seven sanitary officers and one hundred and sixteen non-commissioned officers and men. These were all on the lines of communication and at the bases, and there was no sanitary personnel other than the regimental sanitary detachments and the R.A.M.C. personnel for water duties with units in advance of railheads. The sanitation of various units was carried out by the regimental sanitary detachments, acting under the instructions of the medical officer attached to the unit. There was, in consequence, no sanitary officer with corps or divisional headquarters, except in so far that the D.A.D.M.S. of a division acted as a sanitary officer.

As the duties of the R.A.M.C. sanitary units were thus confined to the lines of communication, the first immediate necessity was the appointment of a sanitary officer to control the work of sanitation at railheads; and when the lines of communication were changed from the Channel to the Atlantic bases, two additional sanitary sections were formed at St. Nazaire in November 1914, partly from personnel sent out by the St. John Ambulance Brigade, and partly from men unfit for duty in the front lines.

When the army increased in numbers and the period of trench warfare had commenced, the urgent necessity for an increase of trained sanitary personnel in the front areas to supplement the work of the regimental sanitary detachments became apparent, and the addition of a sanitary section to each division was sanctioned in November 1914. These

* In view of the experience gained in the war, it has now been considered advisable to increase the personnel of the sanitary sections from 25 to 32, including R.A.S.C. personnel, 3 sergeant sanitary inspectors, 8 corporal sanitary inspectors, 1 workshop foreman and 7 trained tradesmen, in addition to sanitary orderlies and privates.

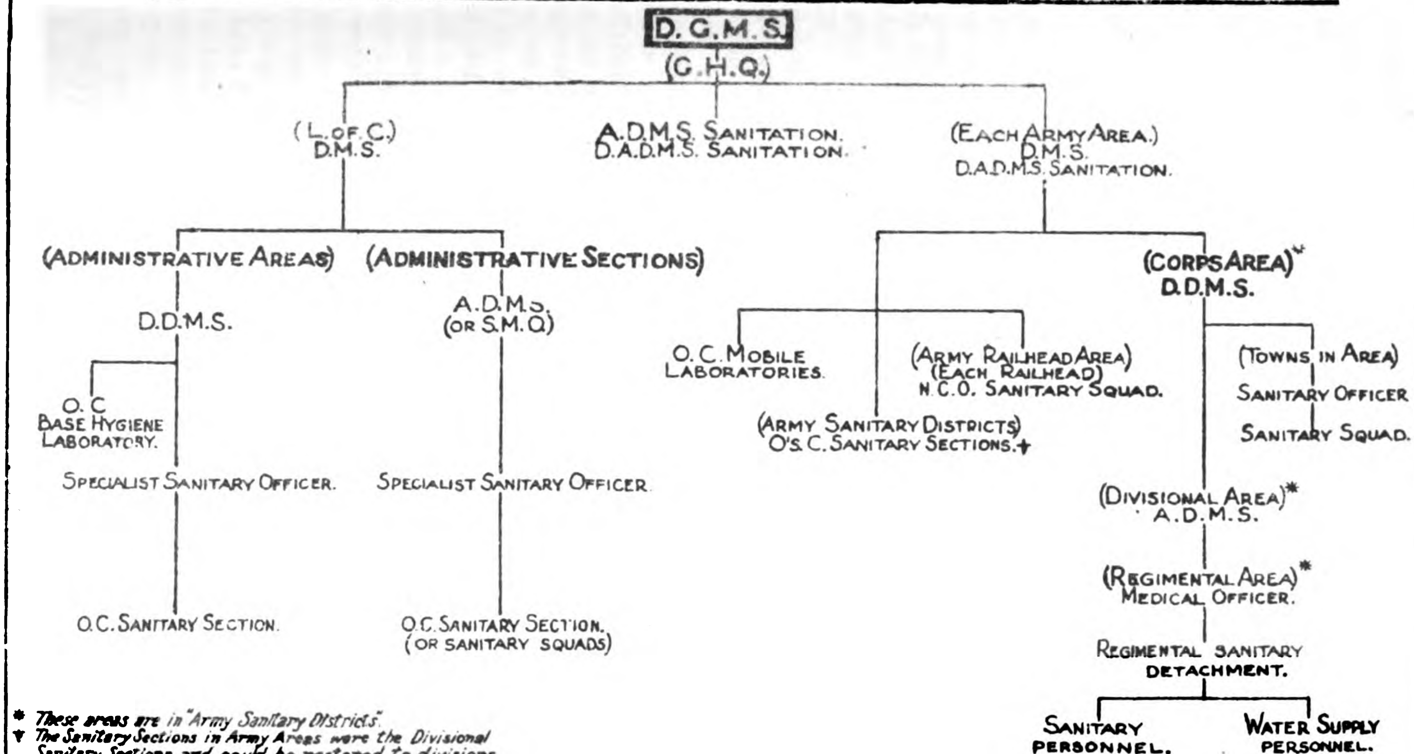
divisional sanitary sections were formed from the personnel of the London Sanitary Companies, and had the same organization as the sanitary sections of the regular R.A.M.C. The introduction of divisional sanitary sections was an unqualified success and led to a great improvement in field sanitation. Their distribution in divisional areas varied in different divisions; in some the men were distributed to regimental areas, in others sanitary squads were detached from the section and attached to brigades. In some cases, the officer commanding acted also as sanitary officer of the division and advised on all matters of sanitation, water supplies and personal hygiene. The initiative and resourcefulness of the officers and men of the sections were remarkable. They rapidly grasped the value of improvization to meet the varying needs and displayed an ingenuity which developed a high standard of efficiency.

By the end of 1917 the trained sanitary personnel in France had increased to 2,500 officers and men, and at the time of the armistice approximately 17,000 were employed on sanitary duties in the various theatres of war. Eighty-four sanitary sections were then on the Western front, and a total of 215 in all theatres of war.

A deputy assistant director for sanitary services had been appointed at general headquarters in 1915 to assist the A.D.M.S. for sanitation, but in May 1916 it also became necessary to appoint a deputy-assistant director for sanitary services to the staff of the D.M.S. of each army in the field. These officers were selected chiefly from specialist sanitary officers at the base, or from the officers commanding sanitary sections. In the same year, most of the towns and villages used as billeting centres were administrated by a Town Commandant, who had at his disposal a certain number of permanently unfit men for conservancy work. As far as possible, a man specially trained in sanitation, generally a non-commissioned officer, was attached for duty with each Town Commandant to act as sanitary inspector. In addition, the general supervision and arrangements in regard to the purification of water supplies, the disposal of refuse, and billeting arrangements were carried out by the sanitary section of the division occupying the area concerned. At each railhead in army areas, a specially trained non-commissioned officer of the R.A.M.C. was attached to the staff of the Railway Transport Officer. He was assisted in his duties by a certain number of men unfit for duty in the front line.

The general scheme of the organization of the sanitary service in the field is shown in Fig. 1.

Table of Sanitary Organization in the Field on the Western Front.



* These areas are in "Army Sanitary Districts".

✝ The Sanitary Sections in Army Areas were the Divisional Sanitary Sections, and could be restored to divisions when required by the military situation. They then came under the administrative control of A.D's M.S. of divisions in the divisional areas.

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FIG. I.

At first the divisional sanitary sections were under divisional control and formed part of the establishment of each division, both European and Indian, but during the Somme offensive in 1916 the usefulness of sanitary sections working under these conditions was greatly impaired by their being moved with their divisions rapidly from one area to another. Whilst the division was in the line the activities of the sanitary section were mainly devoted to the sanitation of the less advanced portions of the area occupied by the divisions. But a division very commonly did not occupy a portion of the line for any considerable period, and by the time its sanitary section had become acquainted with the divisional area and had arranged sanitary details, the division might have to move elsewhere. On the march to another position, the division would have to pass through many villages in rear of the army fronts, but the halt in these villages would be brief, often not more than two or three days. This gave sanitary sections no opportunity of becoming acquainted with the area through which they passed, and little could be effected by them whilst the division was on the march. In fact, it was only during the periods when the division was out of the line and at rest that full opportunities were afforded for sanitary work. These periods, however, were rarely prolonged and by the time sanitary arrangements were organized, the troops would frequently have to proceed elsewhere. Opportunities for good work by sanitary sections under these conditions were necessarily limited, and the best use could not be made of them. As a result, the standard of sanitation in many villages behind the lines through which troops were continually passing was far from satisfactory. Areas in which divisions had rested might at the end of the period and at a cost of considerable labour and material have reached a satisfactory state of sanitation, but when the areas were vacated, sanitary appliances frequently fell into disrepair or were appropriated by the civilian inhabitants. When the areas were re-occupied by other divisions much of the sanitary work done by their predecessors had consequently to be commenced afresh. Further, each sanitary section preferred its own system of carrying out sanitary measures, and its successor in the area was apt to discard some of the work of its predecessor. In order to remedy these defects it was decided, after considerable opposition, to remove the sanitary sections from divisions and allot them to districts within army areas. The divisional sanitary sections were consequently made extra-divisional troops and placed under the control of the directors of medical

services of armies, but for convenience of administration much of their supervision and control was delegated to corps who were responsible for the sanitary administration of the districts in the corps area. This scheme was carried into effect in March 1917, and was attended with uniform success. Sanitary sections of cavalry and colonial divisions, however, remained as divisional units, the former because of the special sanitary work required in connection with horse lines, and the latter chiefly for sentimental reasons. The advantages of the extra-divisional system in non-mobile warfare were numerous. The movements of sanitary sections were reduced to a minimum; each section acquired an intimate knowledge of its district and was able to organize sanitary measures and to maintain and improve the sanitation of the district in a way which would have been impracticable when sections moved with their divisions. The necessity for frequent and useless repetition of sanitary surveys of the same territory and of keeping the army authorities constantly informed of prevailing conditions and needs was likewise obviated. Under the new system each Town Commandant was supplied with a sanitary survey of his district, and incoming troops were supplied with details as to the arrangements for water, billeting, conservancy, and so on. A division marching from one sanitary district to another found a sanitary organization already in existence, efficient sanitary appliances provided, and information available on all matters appertaining to sanitation. Continuity, therefore, in sanitary policy and sanitary effort was obtained to an extent which formerly would have been impossible.

A similar system of allotting sanitary sections to districts in army areas was adopted by the armies of the allied forces. In October 1916, the Under-Secretary of State for army medical services at the French War Office arranged in each district for the immediate appointment of sanitary squads, to be attached to armies in the field. These squads consisted of fifteen men of the auxiliary service, chosen from the youngest age-groups, and included one sergeant and two corporals under the command of a pharmacist. They were required to be specially trained in the general hygiene and sanitation of troops in the field.

In the Italian army similar squads were trained. In some instances, the sergeants and corporals of the squads were priests in the expectation that when they returned to their villages after the war they would spread the knowledge of sanitation which they had acquired in the field amongst the inhabitants.

The duties of the divisional sanitary sections were briefly

outlined when the sections were first appointed, but eventually the scope of their duties was considerably extended. There was always a tendency for formations to rely too much on the efforts of the sanitary sections to supervise and administer matters not strictly within their province. Baths, laundries, and even cinemas in some cases were worked under their supervision and direction. It was consequently found necessary to curtail these activities in order to avoid neglect of their legitimate duties. It was also necessary to prevent the labour gangs working under the sanitary sections from being used to relieve units of their responsibility in carrying out sanitary work which properly devolved upon them. The duties of a sanitary section consisted chiefly in exercising skilled supervision over the labour employed in the removal and destruction of excreta and refuse; in the construction of field latrines and other sanitary works, when engineer labour was not available; the disinfection of billets and of clothing and other articles when infectious disease occurred; the supervision of bathing and disinfestation stations; the supervision, purification and protection of water supplies and general sanitary police duties. They were also available to give instruction to units in technical sanitary matters. In many respects the duties of the non-commissioned officers and men were, in fact, similar to those of sanitary inspectors in civil life.

The work of sanitary sections on the lines of communication was similar, but owing to the large areas over which they were required to operate, they were frequently augmented by one or more sanitary squads. The establishment of each sanitary section included a workshop in which emergency constructional work, as well as the manufacture of models for instructional purposes, was carried out by skilled workmen, the material being provided by the Royal Engineers, or obtained in other ways. In these workshops the personnel of the sanitary sections produced work of exceptional value both in design and workmanship.

The personnel of sanitary sections and squads wore either a yellow arm badge stamped with a letter "S" in red, or the military police badge. The yellow badge was unpopular.

In regard to the distribution of duties, the area supervised by a sanitary section was subdivided into sub-areas, for convenience of administration. In most areas five or six sub-areas were formed. One sergeant, acting as a sanitary inspector, and assisted by one man, was placed in charge of each sub-area and held responsible for its general sanitation. The sergeant

reported daily or twice weekly to the officer commanding the section.

In the case where a Town Commandant was included in a sub-area, the duties included assistance to the Town Commandant in regard to sanitation and also supervision of work in connection with sanitary improvements.

The officer commanding the sanitary section forwarded a detailed report of the work carried out by this section each month to the Director-General, for transmission to the A.D.M.S., Sanitation, whose office in France was with the D.M.S. at the headquarters of the lines of communication. Conferences were arranged from time to time, consisting of officers commanding sanitary sections, deputy assistant directors of medical services for sanitation with army headquarters, and the Assistant Director of Medical Services, Sanitation, General Headquarters, to discuss various problems and to receive information and decide on general lines of policy.

Sanitary squads were employed chiefly at railheads and with smaller units and camps, both in army areas and on the lines of communication. They were capable of being sent forward at a moment's notice, either to supplement a sanitary section or to take over important duties in any area.

Many of the sanitary sections on the lines of communication were formed from existing sanitary squads, the personnel of which consisted of fully trained and experienced men. The duties of the squads were similar to those of the sections. Those at railheads in front areas were, however, controlled from the lines of communication, a form of control which had been instituted in 1914 by the appointment of a Deputy-Assistant Director for Sanitation of railheads, and which was, for some unknown reason, continued long after the necessity of such control had ceased to exist.

The regimental sanitary detachments acting under the medical officer of the unit were responsible throughout the whole war for much of the sanitation which was carried out under arduous conditions in the advanced part of the line. They co-operated with the divisional sanitary sections.

The trained sanitary personnel in the field was reinforced by a number of men from labour battalions, divisional employment companies, and by men of a category unfit for service in the front line. They were employed in conservancy duties in camps, towns and in the field.

In the early months of the war the need for hygiene laboratories in advance of railheads became apparent. It was found that

valuable time was lost when samples had to be sent to the base for examination, and that many circumstances affecting the health of troops were arising, the investigation of which had to be carried out on the spot if it was to be of any real

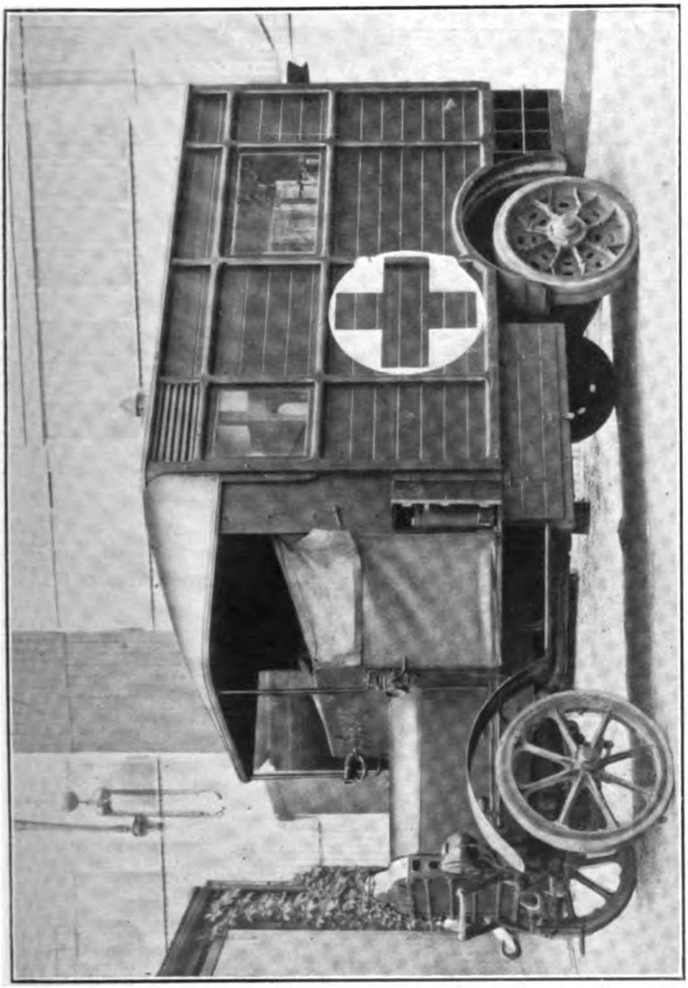

Fig. 2.—Mobile Hygiene Laboratory (exterior).

value. This applied more especially to the examination of water supplies, where analysis must always be combined with an enquiry as to the source of origin of the supply.

Consequently in October 1914 the Commander-in-Chief of the

British Expeditionary Force in France requested the War Office to send out pathological and hygiene mobile laboratories for work in the forward areas. This request was immediately complied with, and the first hygiene mobile laboratory (Figs. 2 and 3) arrived in France in November 1914, and was at once sent to do

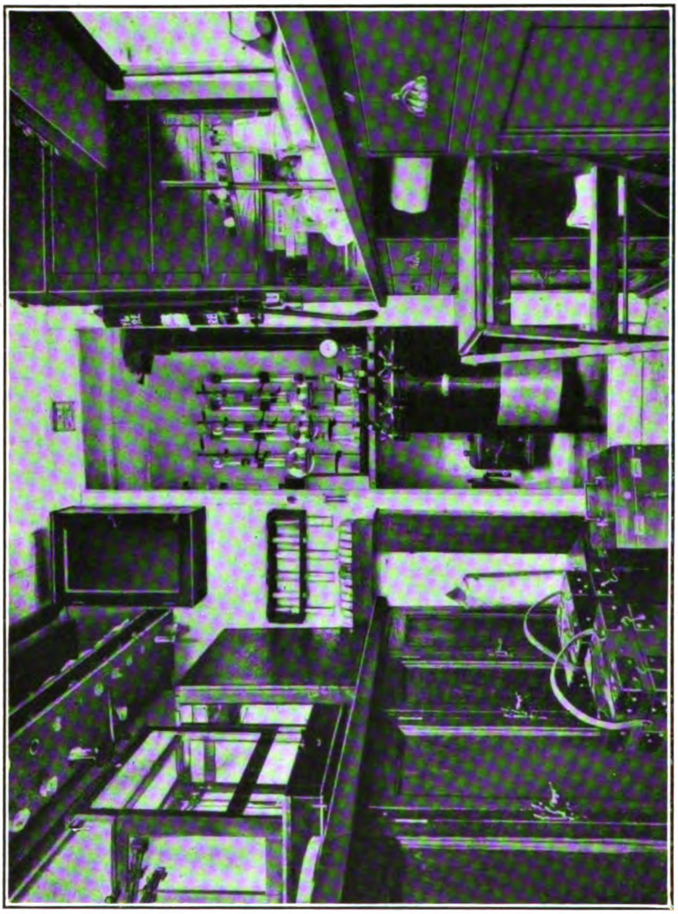

Fig. 3.—Mobile Hygiene Laboratory (interior).

duty in the Second Army area. Subsequently in France there were altogether eight of these laboratories, and in Italy two, but for service in the latter country the laboratories were detailed in 1917 from the eight sent to France. In Salonika, a laboratory, with equipment specially designed for portability and capable of being packed in a small number of special cases, was in use from the earliest days.

One laboratory was considered sufficient for the needs of an army in the field, but in 1918, when the army areas in France were more extended and mobile warfare more general, an additional laboratory for two of the armies was found necessary. Each laboratory was mounted on a 3-ton chassis, its combined weight being 5 tons. It was fully equipped to carry out in the field both analyses of water and analytical work in connection with general hygiene, and was fitted with the necessary benches, cupboards, sterilizers and ovens, which with few exceptions were found in practice to meet all requirements. The laboratories were also in course of time supplied with a light motor car for intercommunication and collection of necessary samples. It was customary to locate the laboratory in some convenient building, where greater laboratory space could be obtained.

The laboratories were staffed by specially trained personnel, all of whom showed great ability, and in many instances carried out valuable research on problems which arose, and they worked in close liaison with the sanitary sections of their army.

The original personnel of the laboratories consisted of one officer of the rank of major or captain, and a trained laboratory attendant with the rank of staff-sergeant or sergeant; this was increased later to two officers.

Although the chief work of the laboratories was to examine water and water supplies, the efficiency of the chlorination of water in the water carts, and other means of purification of water, they carried out, in addition, much routine work in connection with particular circumstances affecting the health of the troops, such as, examination of foods and detection of poisons.

A comprehensive enquiry, carried out by the officer commanding No. 1 Laboratory and others in the Second Army area in 1916–17, into the presence of arsenic in beer sold in estaminets and in the glucose from which the beer was brewed, may be quoted as an example of the work of these laboratories. The results of this enquiry were communicated to the French and Belgian authorities, with a view to their taking action, and consequently the trouble was abated.

Work was also done in the examination of sweets which were supposed to have been dropped from enemy aeroplanes, and were suspected to contain poison, and also of water found in shell holes contaminated by poison gas from shells. In addition, a general examination was undertaken of water from wells in villages which had been occupied and subsequently vacated

by the enemy. Although manure, the bodies of animals and other refuse were frequently found in these wells, no evidence of intentional poisoning was found.

In November 1918, an outbreak of arsenical poisoning occurred among French civilians at St. Amand, which was reported by the officer commanding No. 41 Sanitary Section. This was traced to bread, which was found to contain 0·91 per cent. of arsenic, and considerable quantities of arsenious acid were found in a single sack of flour from which the bread in question had been made. The incriminated sack of flour was part of a consignment received from a relief committee, but no evidence was available as to how the sack came to contain arsenic. The analysis was carried out by the officer commanding No. 6 Hygiene Mobile Laboratory, and by the officer commanding the Base Hygiene Laboratory at Boulogne.

Although arsenic was discovered in many samples of beer sold in estaminets, in some instances exceeding the limit laid down by the Royal Commission on arsenical poisoning, no cases of poisoning were reported as having occurred among British troops; this was, no doubt, due to the constant examination of articles of food and liquors offered to the troops from civilian sources, which ensured the early detection of poison or adulteration, and to the precautions taken to ensure purity of the supplies.

The officers commanding mobile laboratories, in conjunction with officers commanding sanitary sections, made careful routine examination of the chlorination of water in the regimental water carts, and the results of their tests were reported to the units concerned and to the D.M.S. of the army, who forwarded the reports to the Director-General. In this way the sterilization of the water was controlled.

Early in 1915, a fully equipped chemical and hygiene laboratory was established at Boulogne under the direction of the sanitary officer at that base. The officer in charge, Major Wolff, carried out in addition to his other duties valuable researches in connection with many biological chemical problems. This laboratory, in addition to hygienic work, was also of much assistance to other branches of the army. The Supply, Ordnance, Royal Engineers and Royal Air Force, all made use of it for the elucidation of problems with which they were concerned. Routine examinations of water, food, disinfectants, effluents and clothing were of daily occurrence. The toxicological examination of human organs, of sweets dropped

from aeroplanes, and of other articles suspected of being intentionally poisoned, also was frequently required. For example, the laboratory was called upon to investigate the question of poison in shell hole water, in beer, glucose, bread, flour, and castor oil seeds in oil cake.*

For the supply of drinking water to units there were two water-carts with each infantry battalion or cavalry regiment. Smaller units were provided with one cart, but it was found necessary during the war to increase the establishment in many instances. The selection of water for regimental carts was controlled by the medical officer in charge of the unit, and the purification was carried out by the R.A.M.C. water duty personnel, acting under his instructions. Every water-cart was fitted with two clarifying cylinders, and had arrangements for the sterilization of the clarified water by chloride of lime. In 1915, chlorine test cases were included in the equipment of the water-cart for the purpose of determining the amount of chlorine required to sterilize each sample of water.

With the growth of the armies in France after the first year of the war, the great concentration of men in newly occupied areas and the possibility of an advance into country where water supplies were limited, the whole question of water supply in the field had to be reconsidered. A Water Committee, consisting of the Deputy Engineer-in-Chief, an officer of the General Staff, and the A.D.M.S. for sanitary services, was consequently appointed by the Quartermaster-General, to revise the number of water carts required for each division, and to consider improvements in their construction. The committee drew up a detailed scheme for the water supply in the field, and recommended the provision of water sterilizing barges for use on canals and rivers, and the formation of water tank companies, consisting of mobile sterilization units equipped also with tanks on motor chassis for distributing the water. This Water Committee continued its work throughout the war.

All divisional schemes of water purification were carried out by the commanding Royal Engineer, advice on selection and purification being given by the A.D.M.S. of the division, assisted by the personnel of the sanitary section. The divisional sanitary sections played an important part in supervising measures for the purification of water and co-ordinated the work of the regimental water personnel. Larger schemes of water purification were controlled from General Headquarters. Details of water

* See Hygiene of the War, Vol. II, Chapter VII, for an account of the work of the base laboratory.

organization and experiences in obtaining and purifying supplies will be found in the chapters which deal specially with water supplies.

During the course of the war the sanitary services were necessarily in close touch with the other branches of the medical service, and especially with the pathological and other experts, whose advice and assistance in the prevention of disease were, from an epidemiological point of view, invaluable. The value of accurate and immediate diagnosis in combating infectious disease was early realized, and in this respect the co-operation of the consultants and pathologists with the sanitary officers and sanitary administration was of the greatest importance. The bacteriological specialist was especially of use in detecting carriers of infectious disease, the proper care and disposal of whom in the field called for immediate action, and was one of the features of prevention which, in former wars, had never been attempted on the same scale. In fact, every hygienic measure known to science was carried out during the campaign, and, as a result of the experience daily gained in the field, new and hitherto unconsidered action was taken or tried, frequently with unqualified success.

The early establishment of infectious hospitals, both at the base and in army areas, made it possible immediately to isolate cases of infectious disease as they occurred, and special camps, either separate or in connection with infectious hospitals, were arranged as required for the reception of contacts and carriers. It was difficult to decide as to the number of beds which should be kept available for cases of infectious disease, and, as a result of the experience in the South African war, there was a tendency in the earlier part of the war to over-estimate the requirements. This was, however, an error in the right direction, since in the event of a severe epidemic, which was always to be feared, only temporary accommodation, and generally of an unsatisfactory character, would have been available. Eventually, it was decided to maintain three beds per 1,000 troops for isolation purposes, and this proved a correct estimate, so long as there was no outbreak of disease in epidemic form. At each hospital, however, a site was retained where temporary extension, either in the form of tents or marquees, could be provided at a moment's notice.

During the prevalence of dysentery in 1917 and 1918 special dysentery centres, formed usually by field ambulances or casualty clearing stations, were organized in army areas, to which cases passing blood and mucus and diagnosed as clinical dysentery

were sent. All other cases of diarrhœa were sent to a field ambulance for bacteriological examination and for treatment, until the diarrhœa had ceased and the patient could take a full diet without relapse. This ensured that all men suffering from diarrhœa were immediately taken out of the line, that accurate diagnosis could be made, and that mild cases were not evacuated to the base. In this way a great saving in man power was effected, at a time when the presence of every available man in the line was of material importance. Before these measures were adopted, men evacuated to the base and sent to England frequently did not return for many months. The thorough and immediate separation of cases of diarrhœa was also an important and practical measure of prevention, and was carried out to the fullest extent, particularly at the front or in places where overcrowding was unavoidable. It was discovered that men who had served in the East and who had recovered from dysentery were constantly passing through draft supplying units, such as base depôts. Among these were included carriers of the disease, and in such circumstances the possibility of an outbreak, especially during the fly season, involving serious consequences was to be feared. Such an outbreak actually did occur at Etaples in 1917, and caused considerable anxiety.

An important measure of prevention was the early notification of disease. During the war, in addition to the diseases notifiable under the Infectious Diseases (Extension) Notification Act, it was found necessary to include many more, such as trench fever, scabies, nephritis, epidemic jaundice, influenza, broncho-pneumonia, pneumonia, venereal disease and dysentery. The chief object of notification was to afford means for the early control of the disease. The earlier a case was notified and under control the more quickly was prevention assured. Notification in the field also enabled isolated cases to be linked together and traced to a common origin. In France, immediate notification of all infectious diseases was required to be made to the Director-General and to the Assistant Director of Medical Services for Sanitation.

Hospitals at the bases to which sick were evacuated from the armies were required to notify by wire all cases to the headquarters of the lines of communication, to the Director-General, Medical Services, G.H.Q., and to the Director of Medical Services of the army from which the case had been evacuated, in order that immediate steps to investigate its origin and prevent further infection could be taken. A nominal roll of deaths from infectious disease was also sent weekly to General Headquarters.

In the event of cases of plague, typhus, cholera or smallpox occurring, special wires were required. In addition, the deputy assistant directors of medical services for sanitation at the headquarters of armies, and the specialist sanitary officers at the bases compiled an infectious disease register and submitted an annual report. A special case sheet for the notification of infectious disease had to be prepared by the medical officer who might be in charge of a case in any of the medical units. It was forwarded to the Assistant Director of Medical Services, Sanitation, who compiled infectious disease returns from the sheets and submitted a return each month, to the Director-General, Medical Services, both at G.H.Q. and at the War Office, giving the incidence ratio per 100,000 for British, and per 10,000 for Indian troops, the number of deaths and case mortality of each disease.

The strength of the army on which the rates were calculated was based on the weekly returns of ration and feeding strength furnished by the Director of Supplies in all theatres of war. Any fallacy that there may have been ran equally through all the rates, and the rates were, therefore, strictly reliable for the important purpose of comparison in respect of mutual relationship, if any, of the several diseases, and in respect of their individual and relative seasonal prevalence. Duplication of returns did occur, but by careful scrutiny this error was eliminated.

Spot or pin maps were very generally kept by all sanitary officers showing the distribution of disease in their areas. A certain amount of information was thus obtained in tracing the origin and spread of disease, and the maps showed graphically any grouping of disease in a locality, but at the same time they were only useful for short periods and were not of great value in a shifting population, such as that of an army in the field. Spot maps were also, however, of value in indicating the presence of anopheline mosquitoes, and, hence, districts to which malaria patients were likely to be introduced and malaria spread by mosquitoes could be recognized.

During the war, especially in France, the lack of a well-organized bureau, with a sufficiently equipped staff for collecting and compiling statistical returns was greatly felt, but a special statistical officer, Captain Dudfield, was appointed to the staff of the Director of Medical Services, Lines of Communication, for compiling medical statistics, while the special statistics of infectious disease were maintained by the A.D.M.S., Sanitation. It would have been advantageous to have organized a special statistical section in the office of the Director-General of Medical

Services for the purpose of maintaining reliable and accurate statistics from the very commencement.

Instructions were issued from time to time in all theatres of war detailing the procedure for the disposal of contacts with infectious disease. In certain exanthematous diseases, such as smallpox, typhus, plague and cholera, there was no question as to the necessity or extent of segregation, but in the case of mumps, measles, rose measles and scarlet fever, there was considerable divergence of opinion, and in many cases segregation was in excess of actual requirements. A decision in regard to the segregation of contacts was often one of extreme difficulty and had to be carefully weighed and considered, as it often involved dislocation of movements of troops at a time when men were most required in the line. For purposes of limiting segregation, contacts of infectious diseases were defined as men occupying a tent or the same room in a billet; men in barrack-rooms, who had been sleeping on each side of and the three sleeping opposite to a case of infectious disease within the previous ten days; and men who had been intimately associated with a case during the probable infective period.

Experience in the field proved that in the case of scarlet fever, medical inspection and segregation of direct contacts were quite sufficient, and the disease, always mild in character, showed no tendency to spread to any great extent. In the case of measles, there was a tendency at the commencement of the war to segregate large numbers of contacts, such as whole companies or even battalions, but this procedure was at once modified, instructions being circulated to rely chiefly on daily medical inspection from the seventh to eighteenth day after contact had occurred. Where isolation of measles contacts had systematically been carried out, it was found that at the most only 10 per cent. contracted the disease, and hence, the value of segregating a large number of men other than direct contacts was open to question. There was probably no disease on active service which caused so much dislocation of the movements of troops as measles. The high incidence was mainly due to the presence of recruits from sparsely populated districts or from centres in which the disease was uncommon and where the local inhabitants had not been exposed to infection previously. This was specially so in the case of recruits from the Highlands and Islands, and from New Zealand, who had no previous immunity and were especially susceptible in the earlier months of the war.

The procedure which was generally found to be sufficient

to prevent the spread of measles in huts or billets was as follows. A thorough examination of the men was made to detect any who appeared to have heavy catarrh or fever ; and the examination was repeated in a week's time, and then every day for the next six days to detect any further crop of cases, which might have been infected from the first case, and so to secure early removal of them to hospital. If a case or a simultaneous group of cases of measles appeared in a unit likely to contain a large number of susceptible men, the contacts were segregated for three weeks, or until such time as the men so isolated had not had a case of measles amongst them for three weeks. If measles occurred in a draft or unit on its way to join a large body of troops, amongst whom there had been no measles prevalence, the draft or unit was kept back or segregated as above.

A considerable number of men arrived in France who were incubating disease, and outbreaks of measles and mumps on arrival were at one time of frequent occurrence, chiefly owing to the difficulties of eliminating contacts in the United Kingdom at a time when the demand for men was urgent.

Cases of cerebro-spinal fever appeared among the troops in France in 1915. It was introduced by drafts from the United Kingdom, but the result of the stringent and adequate methods of prevention adopted by the home authorities was very soon felt, and the disease in the following years of the war caused little anxiety.

Many men were found to be suffering from scabies and venereal disease on arrival in France. A considerable proportion of the venereal disease cases, frequently amounting to 50 per cent. of the weekly admissions, had been contracted in England by men who had been on leave there. In this connection it is an interesting fact that venereal disease in the French army was also very noticeable among men returning from leave. Thus, in May, June and July 1916, out of 6,431 cases, 5,145 cases had been contracted outside the army zones.

Mumps caused a considerable amount of temporary wastage, especially amongst Indian and Australian troops, and native labourers. The total number of cases recorded for the year 1916 amounted to 4,333, and of these as many as 3,629 were Australians. The prevention of the dissemination of mumps presented many difficulties owing to its extreme infectivity and its long incubation period. It was not possible to obtain successful results by simple isolation of contacts without

rendering large numbers of men unavailable for duty. A system of group segregation suggested by Major R. Tate, the sanitary officer at Etaples, was found to be the most satisfactory way of dealing with the infected troops at the base depôts there. Briefly, the procedure was as follows. Contacts were classified into groups according to the period during which they had been free from infection, thus:—

Group A	contained	men	1 week	free	from	infection.
,, B	,,	,,	2 weeks	,,	,,	,,
,, C	,,	,,	3 ,,	,,	,,	,,
,, D	,,	,,	4 ,,	,,	,,	,,

In each unit the men were grouped in sections of 50 men or more, according to the size of the unit. A note was then made each week of the group in which no case had occurred during the preceding week. After one week free from disease, a group was classified A, after a second week B, and so on. Reinforcements for the front were then selected as far as possible from the last group, D. It was not always possible to adhere rigidly to this, since a greater number of drafts might be required than could have been selected from group D. In such cases, specially selected men were chosen from Group C, and their names and periods of segregation yet to expire were forwarded to the A.D.M.S. of the division to which they were transferred.

The disposal of contacts in the case of diphtheria was carried out on the usual lines. The disease never made much headway amongst the British troops in France, although there was a tendency to increase in 1917, when the highest monthly rate reached 13·6 per 100,000. The disease was, however, very prevalent amongst the troops in Sinai and Palestine. It was found that the isolation of positive carriers, detected by bacteriological examination, was sufficient to control all outbreaks, and very few chronic carriers were noted. The differentiation between virulent and non-virulent carriers was unfortunately not carried out, possibly owing to difficulties in technique. The use of prophylactic administration of antitoxin was also not resorted to, although the Canadians employed it with success in the case of a severe outbreak among civilian children in an area occupied by them on the Western front. In addition to the usual measures, the Americans applied the Schick test to a whole unit if the outbreak was extensive, and cases found to be positive were then immunized. Special attention was paid to the sterilization of all eating utensils by

washing them in soapsuds and finally sterilizing in boiling water.

Arrangements were made from the very commencement of the war, whereby all sanitary officers kept in touch with and assisted the local sanitary authority, both at home and overseas. From the early days of the war a system of dual notification of disease was instituted whenever possible, whereby a weekly return of infectious disease among civilians in army zones was rendered by the allied civil authority and similarly a return of cases among troops was supplied to the civil authority by the British military sanitary officer concerned. This information allowed of many infected houses being placed out of bounds to the troops. House to house visitation for the detection of cases of infectious disease was instituted and infectious cases isolated in special hospital buildings extemporized from existing buildings; while contacts were segregated in temporary hutted camps and the houses disinfected.

Other matters which from time to time needed consideration were the compulsory notification of infectious diseases among the civil population; the compulsory removal to hospital of civilians suffering from communicable disease; prophylactic inoculation and vaccination on the occurrence of outbreaks of smallpox, cholera and enteric fever; extensive operations for the sterilization of infected public water supplies and the evacuation of refugees from advanced areas.

It frequently happened that troops had to be billeted in towns which required strenuous sanitary cleansing. One of the larger towns in France occupied by the British in 1916, for example, was described as having its streets dirty and unswept, the gutters and main surface drains choked with thick mud, and piles of rubbish and garbage scattered on the footpaths in the main streets and littering the side streets, and the billets filled with refuse of every kind. There were no public latrines of any description. In some cases units had erected latrines at the back of their billets, and the excreta were disposed of by burial or by dumping outside the town area. There were no signs of urine pits and there was not a single instance of an efficient grease trap in billets.

In order to remedy this state of affairs, a series of town sanitary orders was drawn up, printed and issued by the Town Major to each unit on taking over billets. A definite system was organized for the disposal of refuse and excreta. Two large destructors were installed in the vicinity of the two town refuse dumps. Excreta were collected from all billets and

disposed of by incineration at one or other of the public destructors. The refuse from billets was collected each morning and disposed of in a similar manner. Arrangements were made for the civilian inhabitants to provide boxes or buckets in which they placed refuse before 9 a.m. daily, when it was removed by civilian personnel and disposed of at the town dumps. Previously this refuse had been deposited on the footpath and was removed twice a week only. Fatigue parties were obtained from units billeted in the town. These parties kept the streets clean, cleared all open spaces of refuse that had been dumped there, wired them off and put up notices forbidding civilians or soldiers to dump refuse on them. In addition, the surface drains near the centre of the town were sunk three feet and closed in. Billets that were occupied permanently were provided with well-constructed fly-proof latrines, ablution benches and washing bowls. A large public fly-proof latrine with urinal was erected near the principal square with direction boards placed in prominent positions. Public conveniences were also erected near the railway station in the vicinity of the divisional cinema and in other suitable positions.

The co-operation of the Belgian sanitary authorities during the serious outbreak of typhoid fever among the civil population in Flanders in 1915, the co-operation of the French authorities in the quarantine arrangements for Portuguese troops landing in France from typhus-stricken areas in Portugal, the measures required to be taken in the case of refugees from army fronts or infected areas, and the re-occupation of towns recovered from the enemy, were instances of the benefit of a close liaison between the British and the allied sanitary authorities.

In 1916 an Inter-Allied Sanitary Conference was inaugurated in Paris. In addition to the full meetings of the conference, which was held in Paris annually and attended by a large number of delegates from all the allied nations, permanent delegates, who met monthly and reported the particulars of any difficult or unusual problem in hygiene that affected the troops, were appointed by each of the allies. In this way ideas were exchanged, new problems were discussed from many different points of view, and measures which had proved to be successful in one army were adopted by another.

The proceedings of the conferences were confidential and were not published during the war. Meetings were held up to 1919, and the duties which were undertaken by the members

of the conference became merged after the war in those of the *Office Internationale d'Hygiène Publique.*

In Salonika, the Director of Medical Services of the British Expeditionary Force instituted an International Hygiene Committee, in 1915, which met weekly in the French Hygiene Laboratory under his presidency. The Directors of the Medical Services of the French Expeditionary Force and Navy, the Greek medical officer of health for Macedonia and the specialist sanitary officers and bacteriologists of the British and French General Headquarters, were members of the committee. Not only were the allied forces kept informed at these meetings of the existence of infectious disease, but they co-operated actively in organizing measures of prevention and in carrying out sanitary reconnaissances of the areas occupied by or likely to be occupied by the troops.

The clothing and equipment of the soldier received a great deal of attention on both physiological and economic grounds. The Quartermaster-General's Department was always in close touch with the medical service on all these questions. In addition to arrangements both for summer and winter issues of clothing, a large amount of specially devised clothing and equipment was from time to time required, which included, for example, special clothing for motor drivers, army bakers, Women's Army Auxiliary Corps and special labourers, and for wear in certain sub-tropical or sub-arctic areas when the advice of experts with naval or military experience was sought.

The equipment authorized prior to the war was devised to enable the soldier to carry his load most comfortably and with the least expenditure of energy, while yet permitting effective and immediate use of each individual item.

With the increase of impedimenta necessitated by the conditions of modern war, the weight the soldier was called upon to carry was far in excess of the economic load. Continued demands were made until the equipment which the infantry soldier in France was often called upon to carry amounted in winter to about 80½ lb., and when the clothing was wet and caked in mud this weight was greatly exceeded. Many of the men in the army were below the standard demanded in peace time and were performing unaccustomed work. As a result, the limit of load which could be authorized for carefully trained soldiers was exceeded for many men of inferior physical type, especially if they had not undergone the graduated training which it is possible to give in times of peace. In many divisions efforts were made to reduce as

far as possible, the load carried on the march, by making arrangements for carrying part of the equipment on the divisional transport.

Owing to the ever-present danger of fly-borne disease it was necessary to organize a vigorous anti-fly campaign. The general policy aimed at was to maintain as high a standard of general sanitation as possible, with the object of reducing to a minimum conditions favourable for fly breeding. It was recognized that success in reduction of flies was largely dependent on the efficient organization of anti-fly measures during the cold season and in advance of the actual breeding season.

As regards the Western front, flies were prevalent in the autumn of 1914, but there was no undue prevalence until the advance in 1916, when areas which had previously been occupied by the enemy were taken over. In Marseilles, flies were prevalent all the year round, and in Salonika, Egypt, Mesopotamia and East Africa they were always a source of great annoyance and considerable anxiety.

In April 1915, Professor Robert Newstead and Professor Jack came to France, and with Major Austen formed a special entomological committee to study the question of fly prevention. Details of the special measures adopted in the organization for the prevention of flies are described in Chapter XI of the second volume of the Hygiene of the War. But generally, the most important part in the campaign against them was the incineration of waste products. Where incinerators were installed and worked under supervision, a high standard of general sanitation and freedom from flies was generally found.

In 1915, the sanitary organization in Egypt was under the control of a Principal Director of Medical Services for the Mediterranean, which included Gallipoli, Salonika, Cyprus, Malta, and the Mediterranean areas generally. Owing to the extraordinary difficulty of communication across seas the supervision of any other place but Egypt was purely nominal, and the appointment of a Principal Director of Medical Services was abolished in 1916, and the sanitary administration of Egypt and Palestine devolved on the D.M.S. on the staff of the General Officer Commanding-in-Chief, Egypt and Palestine. Attached to the Principal Director of Medical Services was a Medical Advisory Committee.* Members of the committee

* The Medical Advisory Committee consisted of Colonel W. Hunter, Lieut.-Colonel Andrew Balfour and Lieut.-Colonel G. S. Buchanan. Lieut.-Colonel L. G. Dudgeon accompanied the committee as a bacteriologist; he was succeeded by Lieut.-Colonel J. C. G. Ledingham.

visited Gallipoli during the operations of the Dardanelles Expeditionary Force, also Mudros, Salonika and Mesopotamia. The results of the Mesopotamia enquiries were brought to the notice of the Indian Government, and were published by it. The reports so published in India were six in number, dealing with the Basra base, Shaikh-Saad, the 3rd Indian Army Corps, the lines of communication from Shaikh-Saad to Basra, the Euphrates and Karun area, and a general final report.

In Egypt the Medical Advisory Committee made inspections comparable with those of the Army Sanitary Committee at home and in France. A sanitary statistical bureau was formed in Cairo by the Principal Director of Medical Services who also appointed a special committee to outline a conservancy scheme for the whole of Egypt. Two central laboratories were formed, one at Alexandria and the other in the Egyptian Public Health Laboratory in Cairo. Later a central laboratory was formed at Port Said and a travelling laboratory was established in a railway carriage.

After the Mediterranean base organization was broken up, the sanitary organization of the Egyptian Expeditionary Force followed much the same lines as those in other theatres of war.

After the War Office took over the administration of the military operations in Mesopotamia, the scheme of sanitary organization shown in Fig. 4 was worked out in 1916.

Under the sanitary headquarters there were three main departments, namely, the engineering department, the laboratory department and the sanitary department.

The engineering department was established for the purpose of carrying out the engineering work associated with sanitation.

The laboratory was divided into a central laboratory at Basra, to which was attached a launch, "Lady Carmichael"; a central laboratory at Amara, to which the launch "Hoogly" was attached; a laboratory barge (being a mobile unit) for the Tigris front; 12 first-class hospital laboratories (6 at Basra, 4 at Amara, 1 at Nasiriya and 1 at Shaikh-Saad); and 18 second-class hospital laboratories (7 at Basra, 6 at Amara and 1 at each of the following places: Kurna, Khamisiyeh, Ahwaz, Bushire and Shaikh-Saad).

The sanitary department was divided into 5 areas—Basra, Amara, Shaikh-Saad, Nasiriya and Tigris front, and the last was subdivided into the areas allotted to the four divisions (3rd, 7th, 13th and 14th).

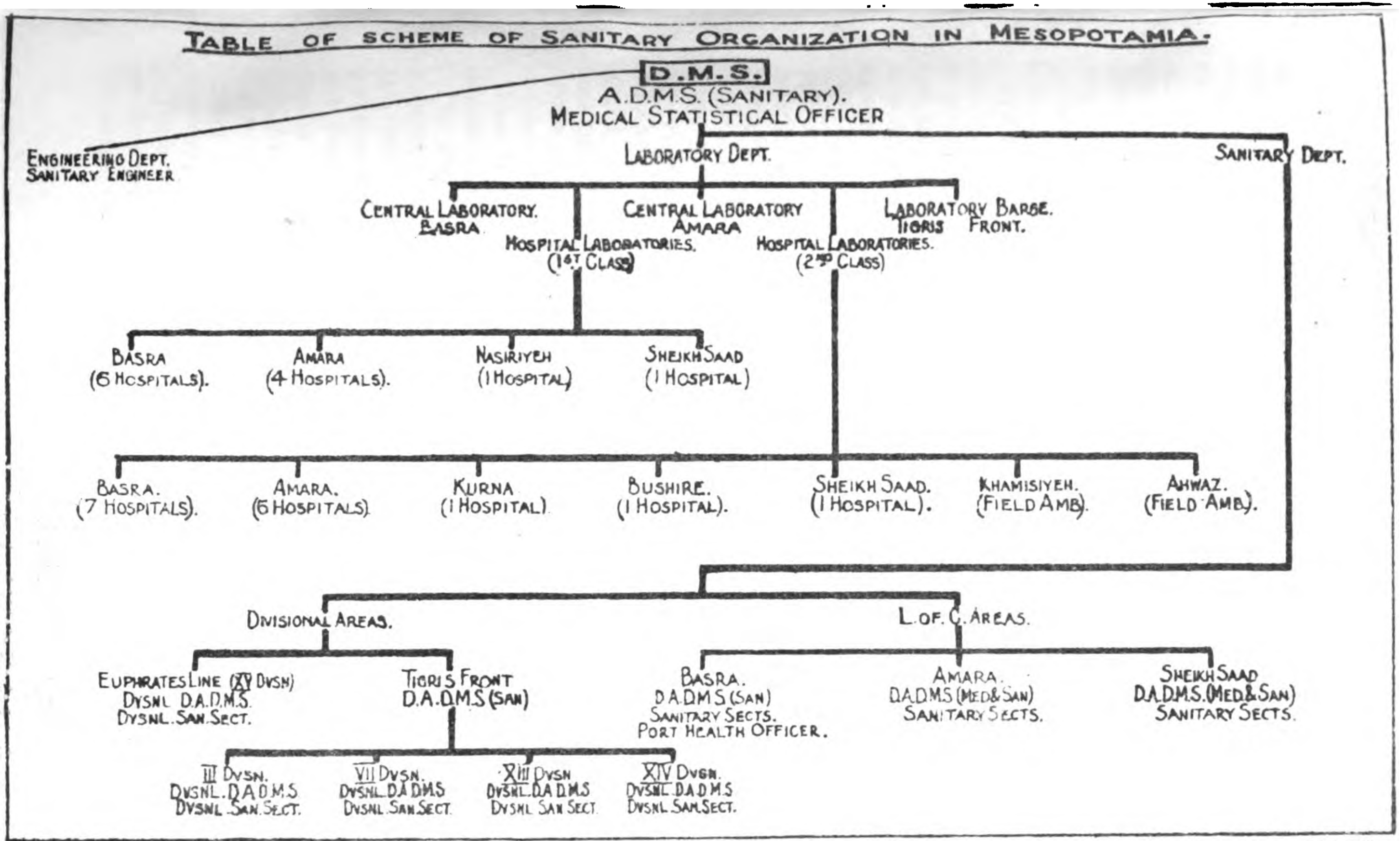

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FIG. 4.

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The central laboratory at Basra contained laboratories for bacteriological, protozoological (with malaria) and chemical investigations. It was established in a house in Basra City but afterwards it was found to be inconveniently placed, and later a large hulk, called the "Elphinstone," became available, and the central laboratory was transferred to it on 8th January, 1917. The hulk was well and suitably fitted up and was moored at a convenient spot near the hospital area.

The central laboratory at Amara was required for clinical work and investigation.

The laboratory barge (regarded as a central laboratory) for the Tigris front was required for clinical bacteriology and investigation. No. 4 Barge was handed over and fitted out as this laboratory. It was complete and in working order on 12th August, 1916, and was moored to the right bank at Arab village.

The launches attached to the central laboratories at Basra and Amara were required for investigation of outbreaks and malarial conditions, for engineering measures and visitation generally.

The functions of these laboratories were the investigation of the spread of disease and the special diseases of the country; the examination of water supplies; disinfecting processes and their efficiency; consultant; and the supply of cultures, special media, special stains and special requisites. In principle they were not for clinical work, but actually at Amara and at the front they had to take up a large amount of this work.

The hospital laboratories were intended to carry out clinical work and were definitely attached to hospitals.

The sanitary work was carried out by the various sections working under the authority of the D.A.D.M.S., Sanitation, at the various places. At some of the stations the D.A.D.M.S. performed both medical and sanitary duties, but at Amara and Basra their sanitary work occupied their time to the utmost.

Eight entomological assistants had been sent out for work in the laboratories. Their contract expired at the end of September 1916, and as their services were no longer required, they were sent back to India.

There was a civil medical practitioner at Basra employed by the Turkish Government as officiating Port Health Officer. On arrival of the British troops he was taken on by the British

Government and as his work was of course enormously increased, his duties had to be definitely laid down. Accordingly these were formulated as follows: (1) To visit all ships entering the port and grant pratique (except H.M. ships and hospital ships); (2) to visit all cases of sickness on board ships lying in the river; (3) to investigate deaths on board and grant death certificates, and arrange disposal; (4) to inspect daily all people at the cholera blockade camp; (5) to inspect at the plague blockade camp all people passing up the river; (6) to be in medical charge of Mushari camp (4 miles down the river) for isolation of contacts of plague and cholera; and (7) to issue bills of health and certificates to outgoing ships if necessary.

The sanitation of Basra was originally organized under the direction of Lieut.-Colonel James, I.M.S., who arranged that the D.A.D.M.S., Sanitation, of Basra, should undertake and be responsible to the A.D.M.S., Base, for the supervision and control of the whole area, and that his executive staff should be No. 10 Sanitary Section, of which the officer commanding was his assistant sanitary officer. The work he had to carry out was in connection with the water supply, slaughter-houses, markets, restaurants, disinfection, refuse destructors, improvement of congested and insanitary areas, general anti-malarial and anti-fly measures and the control of infectious disease. The whole area was divided into five areas—(1) Basra city area, (2) Basra river front, (3) Ashar area, (4) hospital area (each hospital being responsible for its own area), (5) Makina area.

It soon became evident, however, that this scheme was not extensive enough in view of the large increase of the garrison, and especially of the labour personnel and the increasing area occupied as " Basra base." It was impossible to carry out the work with the staff allotted to one sanitary section. Hence the whole scheme had to be re-organized. The " Basra base " was divided into three areas, (1) from the Serajim at the extreme south, as far north as the Ashar creek, excluding Basra city, but including the Tanooma area across the river, (2) the Ashar creek to the Robat creek, excluding Ashar city, (3) Robat creek to the brick kilns above Magill.

One sanitary section was allotted to each of the three areas and an extra sanitary section was distributed to provide trained supervision of the various sweeper squads. The officer commanding each sanitary section was responsible for

the sanitation of the area allotted to him and served under the A.D.M.S., Base, to whom he submitted reports.

By this arrangement the whole area allotted to the troops was divided up, but Basra City and Ashar with their extensive bazaars were not included. These places were put under the supervision of the health officer of Basra, and Ashar under the civil surgeon.

CHAPTER II.

SCHOOLS OF SANITATION AND INSTRUCTION IN HYGIENE.

HISTORY has demonstrated again and again the power of disease to decide the fate of armies. Up to the time of the war statistics had shown an enormous preponderance of death and disability caused by sickness over that resulting from enemy action. This proportion had been disturbed by the increasing lethal power of modern offensive methods, but at the outbreak of the war disease still constituted the greatest menace to armies in the field. Moreover, in view of the fact that such danger increases in proportion to the number of troops engaged, it was realized that in both the West and East—more especially the latter—sanitation was the key to success.

The responsibility for carrying out sanitary measures could not be confined to any one branch or grade in the army. The Army Medical Service could instruct, advise, exhort, but alone it was helpless, and the regulations consequently emphasized the responsibility of all units and ranks, under their respective commanding officers, with regard to measures of hygiene.

The regular army had been specially trained and fully instructed in all matters relating to health under the conditions of a war of movement.

During the war, however, the trained regular soldier was in the minority, and the temporary soldier, a man whose life had been spent in office, workshop or mine, with all the conveniences of civilization to hand, formed the bulk of the army. Moreover, the type of warfare brought problems of its own; men fought in shell holes and in waterlogged trenches; they were compelled to live in "dugouts" deep down in the ground, where all matters of conservancy and ventilation presented new difficulties.

The war was also world-wide; men were fighting in the waterlogged fields of Flanders, in the marshy valleys of Macedonia, in the wildernesses of Mesopotamia, in the deserts of Egypt, in the hills and valleys of Palestine and in the tropical forests of Africa. Each sphere of operations thus presented its own set of problems, upon the solution of which depended the whole success of the campaign.

Consequently instruction in hygiene became imperative, both before troops were drafted overseas and after they had arrived in the field.

One of the most useful lessons of the war, in preventive work, was the value of schools and demonstration centres, where all ranks could be taught the dangers they were likely to encounter and the best methods of dealing with them. The system of education had to be elastic and embrace every unit and every grade in the army.

Experience showed that the system of instruction should include six distinct spheres of work :—

(1) Routine training, in schools of hygiene and cookery at home, with adequate camp training.
(2) Special training in sanitary supervision, water duties, incineration, entomological work, disinfestation and other preventive measures.
(3) Local training at demonstration centres in the field, showing the local conditions with reference to special dangers and difficulties.
(4) Revision courses in the field, given to men resting or temporarily withdrawn from the line.
(5) Popular lectures to men and officers, also propaganda work by means of pamphlets and posters.
(6) Constant discipline in all matters relating to sanitation in the field.

With such a system it was found possible not only to enable men to fight in districts which might have proved veritable death-traps, but even to stimulate enthusiasm in many who hitherto had ignored the value of sanitation or had not realized its significance.

Routine Training.

Routine training in army sanitation took place before the soldier went overseas. It formed part of the general scheme of training, but as far as possible was kept separate from the more purely military side of his training. A multiplicity of drills, fatigues and route marches during the course of sanitary training proved a distinct obstacle to success.

A properly constituted school was capable of dealing with classes drawn from any grade ; sanitary specialists were brought into touch with the most recent work from various fronts ; medical officers received lectures and demonstrations dealing with their duties in the field ; sanitary sections were instructed in the principles and practice of hygiene and elementary brick-work, metal-work, carpentry, sketching and so on ; officers, non-commissioned officers and men were taught the essentials

of field sanitation. A well-equipped school had samples of equipment, foot gear and clothing; working models of all appliances necessary for sanitary work under every conceivable condition of climate and campaign; food models illustrative of the rations issued under various conditions, also of the different types of unsound food which might demand attention from the medical or commanding officer. There was a field exhibit showing incinerators, field ovens, latrines and the like, built as far as possible to the actual dimensions; with smaller models and diagrams for use in the lecture room. Plaster models and pictures illustrating the various conditions, such as trenches, camping grounds and fly-breeding places, were also of great value.

The course of training at such a school varied with each type of class, from the intensive training of men and officers devoted to purely sanitary work to the short course of lectures and demonstrations given to combatant officers. The fact that the latter were responsible for carrying out the details of sanitary work was not lost sight of, and the training of the rank and file had to be detailed, even when it was of an elementary nature.

The battalion medical officer is the sanitary adviser to his commanding officer, and it is, therefore, essential for all army medical officers to be well grounded in the principles and practice of army sanitation, and convinced of its importance. Occasionally during the war the work of disease prevention was hampered by the attitude of certain medical officers who were untrained in sanitation and apt to minimize its value and importance. A knowledge of elementary brickwork, metal-work and carpentry was invaluable to medical officers in the field; and it was also important that they should be able to interpret correctly and intelligently simple plans and diagrams. These subjects were consequently included in the sanitary training for medical officers. Men and officers for special sanitary work in the field required a similar but longer course of training; the officers had to carry out work which corresponded to that of a medical officer of health at home, while the men were, to all intents and purposes, sanitary inspectors. One of the most important qualities for such men is tact, and every effort was made during the course of training to emphasize this point. The possession of this quality had an important bearing upon the fitness of a man for the higher non-commissioned ranks.

Tropical medicine and hygiene were so closely united that

it was found an advantage, in training medical officers for the tropics, to include the clinical side with the preventive.

Three schools which were engaged in routine training in sanitation during the war illustrate the work carried out in this direction.

The London Sanitary Companies.—Repeated and eloquent testimony has been borne to the value of sanitary sections in the field. Many of these sections were trained and equipped at the Headquarters of the 1st and 2nd London Sanitary Companies in the Duke of York's School, Chelsea. The type of man enlisted in these companies in the early days of the war was admirably suited to the work; sanitary inspectors, school teachers, architects, surveyors, plumbers, carpenters and many others with every qualification for success, were enrolled. Sections were urgently needed for the divisions going overseas, and the work of equipment and essential instruction in purely military matters considerably limited the opportunity for special sanitary training. Fortunately this disadvantage was, to a large extent, neutralized by the previous knowledge of the men under training. As time went on, however, the supply of experts became exhausted, and men who were enlisted were ignorant of the work and often unsuited for it. Under such conditions the only hope for success lay in thorough and enthusiastic training, with the power of excluding those whose mental condition rendered them entirely unsuited for this type of work. It also became of vital importance that, so far as the military situation would allow, men should not be removed before the course was completed, as much inefficiency in home camps and abroad had previously been due to this.

The course of training included lectures, demonstrations, practical classes in water duties, etc., drills, fatigues and other military work. In the early days of the war a definite syllabus of routine training was very difficult to carry out, owing to the fact that recruits were coming in daily, and the demand for fully trained men often necessitated the adoption of emergency and intensive methods of training. This instruction very largely fell to the lot of the officer chosen to command the section, frequently a civilian health officer with little previous experience of army methods. He was well grounded in the principles of disease prevention, but needed help in adapting his knowledge to new conditions, and the series of lectures on "Sanitation in War," delivered at the Royal Army Medical College, and subsequently issued in book form, was of the

greatest assistance in translating his previous ideas into the more robust requirements of active service. The fact that the recruits were absolutely ignorant of ordinary military subjects, such as discipline, drills and marching, presented a difficult problem, and often this knowledge had to be gained at the expense of sanitary training. Men destined for sanitary work should, in fact, receive the necessary military training before passing to the school of sanitation. If both are taught together there will always be a tendency for one or the other to be neglected. The history of work at this centre also emphasized another point. Work in a sanitary section is skilled work, work which demands a very high grade, both of physical and mental fitness; the later tendency to regard as suitable men of a low grade, not only physically, but even mentally, lowered the status of the work, and also menaced the whole scheme of sanitary organization in the field. For members of a sanitary section to fulfil their functions, it was essential that they should be regarded as experts, instructors and advisers, and not employed in ordinary fatigue work; but this could never be possible unless careful discrimination was used in the selection of personnel.

At a later stage in the war men were sent to the school in batches, and it became easier to maintain a definite routine of instruction with the assurance that a man would have time to complete his course of training before being drafted overseas.

An exhibition of incinerators, field cookers and other apparatus used in the field was erected, so that men could see types of the actual appliances used. Demonstrations of these models were given to all men under training, and classes of combatant and medical officers visited the school to receive practical instruction.

Such training as was received could only be regarded as preliminary to actual instruction in the field. One of the great defects in teaching during the earlier part of the war at the Duke of York's headquarters lay in the fact that facilities were not provided for sections actually to put into practice the lessons they had learned until the fully equipped section left headquarters for its work in the field. Many officers and men were absorbed by divisions as advisers on camp sanitation and matters of general hygiene in the field, when they had scarcely seen a camp, and many had never previously slept under canvas. The theoretical knowledge was there, and could be quickly applied to camp conditions, but it would have been far better had practical camp training been included

in the syllabus, more especially in view of the importance of first impressions.

School of Army Sanitation, Leeds.—This school was established for training American medical officers serving with the British army in the details of British field sanitation; it was also used for teaching men intended for sanitary duties in the field, and proved of value as a demonstration centre for specialist sanitary officers and others. Especial stress was laid upon the value of visual teaching, and, as far as possible, every type of sanitary appliance used in the field was shown.

The course for American medical officers was very limited in time owing to the exigencies of the campaign, and for this reason the type of teaching seemed to be specially suitable. Lectures were freely illustrated by diagrams and models, and were so arranged as to group the various diseases ætiologically. Such a classification may present many scientific difficulties, but for the study of the prevention of disease it is invaluable. There was too great a tendency to regard sanitary measures as belonging to a system separate from the practice of medicine, although it is only when the close relationship between hygiene and disease is realized that the best results can be obtained.

The syllabus of instruction at the Leeds school was divided into sections. One section dealt with the prevention of disease not due to parasitic invasion. This section included diseases due to exposure (trench foot, sunstroke, bronchitis, "rheumatism," etc.); diseases due to improper food (beri-beri, scurvy, food poisoning, etc.); diseases due to unsuitable construction or use of equipment or clothing (sore feet, heat-stroke, etc.); diseases due to poisons, such as nicotine or alcohol. The whole question of rations and equipment was considered and models were shown illustrating field rations, the vitamine problem, blown tins and other food matters, Samples of equipment, footgear and clothing from every front were shown, and the method of wearing was demonstrated.

A second section dealt with the diseases caused by living organisms, and was divided into four subsections.

(1) Diseases spread by actual contact, such as scabies, gonorrhœa, syphilis and smallpox. This portion of the syllabus was introductory, and included a consideration of general preventive measures, such as diagnosis, notification, isolation, treatment and disinfection, in addition to special preventive measures applicable to each disease.

(2) Diseases spread by mouth-to-mouth infection, "droplet

infection," such as pulmonary tuberculosis, cerebro-spinal meningitis, pneumonic plague and measles. This section included matters connected with ventilation and billeting, in addition to special problems connected with each disease.

Fig. 1.—View of interior, showing various models.

(3) Diseases spread by excrement. This group is of special importance to army work, as it includes many diseases which in the past have caused disaster to armies in the field. The danger of typhoid fever, dysentery and cholera can scarcely be overrated, whilst many worm diseases are spread in a

similar manner. In this section were included sanitary measures of such importance that there was a tendency to limit the sanitary outlook to this section alone. Thus the whole system of water supply, storage, transport and purification was devised with a view to preventing this group of

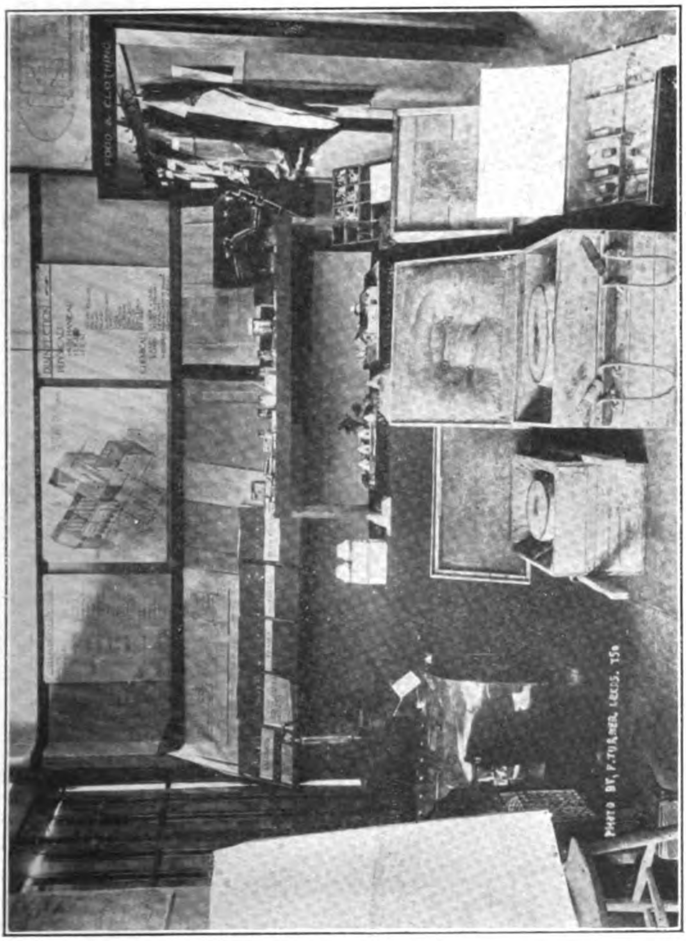

Fig. 2.—View of interior, showing various models

diseases. Latrines, urinals and destructors were designed to limit their incidence. Fly destruction, dust suppression, food protection and general cleanliness were also measures directed against this class of infection, while inoculation was utilized to

fortify the individual resistance against an
in the scheme of sanitary prophylaxis.

(4) Diseases spread by means of biting in
of ever-increasing importance in military

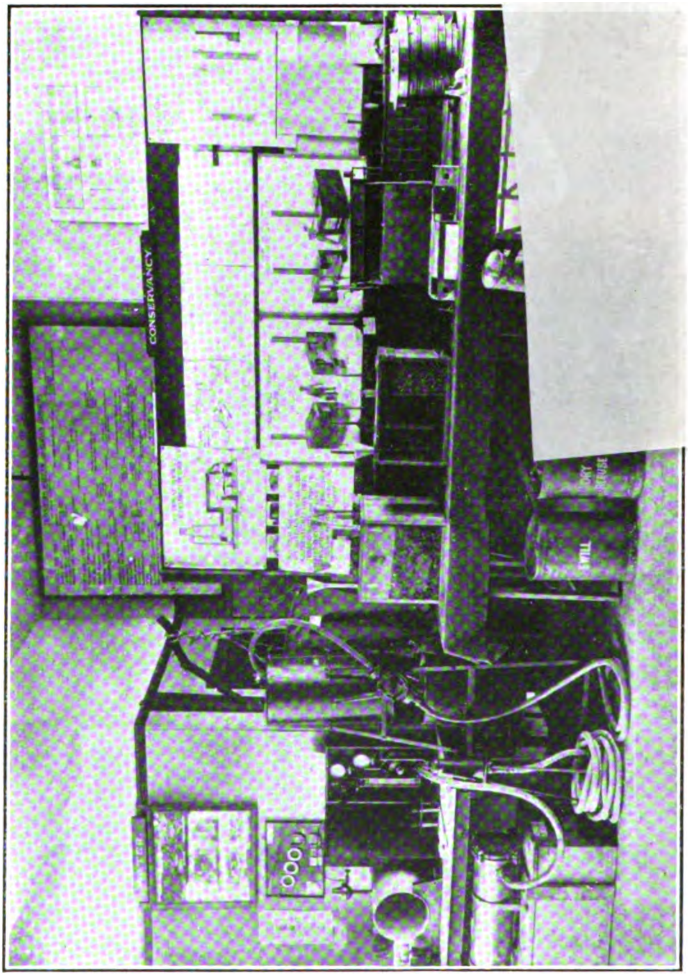

Fig. 3.—View of interior, showing portion of

or in semi-tropical theatres of war. It included malaria, typhus, relapsing fever, phlebotomus fever, trench fever, plague, and other diseases of less importance from a military point of view, such as sleeping sickness. Preventive work in these diseases

depends chiefly upon measures directed against the insect vectors—abolition of breeding grounds, and protection of the individual.

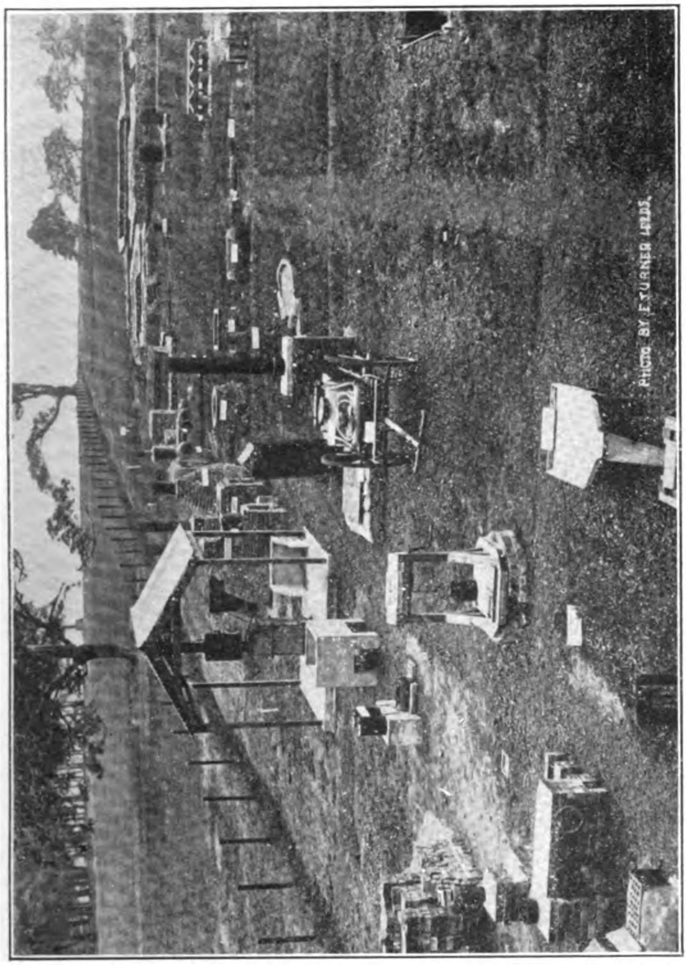

Fig. 4.—General view of outdoor exhibits.

All these subjects were dealt with in lectures and demonstrations illustrated by means of diagrams, pictures and actual working models. In addition, a lecture was given upon the executive and administrative side of the work in the field, with special reference to available personnel and means of getting work done.

In a demonstration centre, where all practical classes were held, there were an indoor exhibition and a field exhibition. The former was so arranged that it illustrated all the various points mentioned in the lectures. Plaster models showed

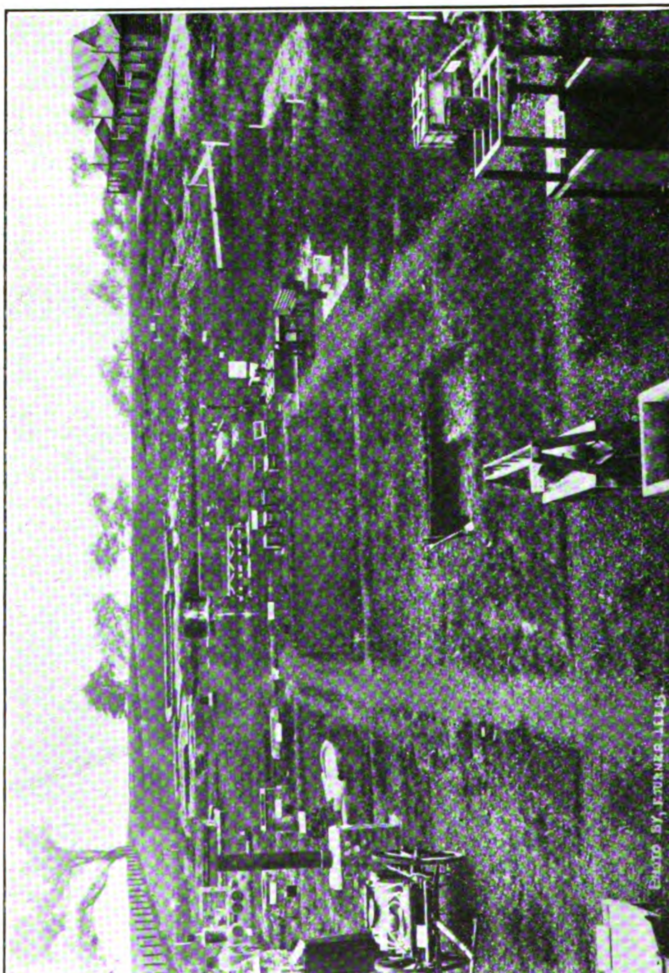

Fig. 5.—General view of outdoor exhibits.

areas, billets and camps on the various fronts; pictures showed insect breeding places; diagrams illustrated sanitary appliances. Cases of specimens and coloured illustrations showed most of the important insect vectors of disease.

Wooden and plaster models of incinerators, latrines, destructor centres, bath-houses, and so on were shown, and all apparatus used for the purification and examination of water were demonstrated and actually used by the class. Models of disinfectors in common use and other details connected with this work were included. (Figs. 1–3).

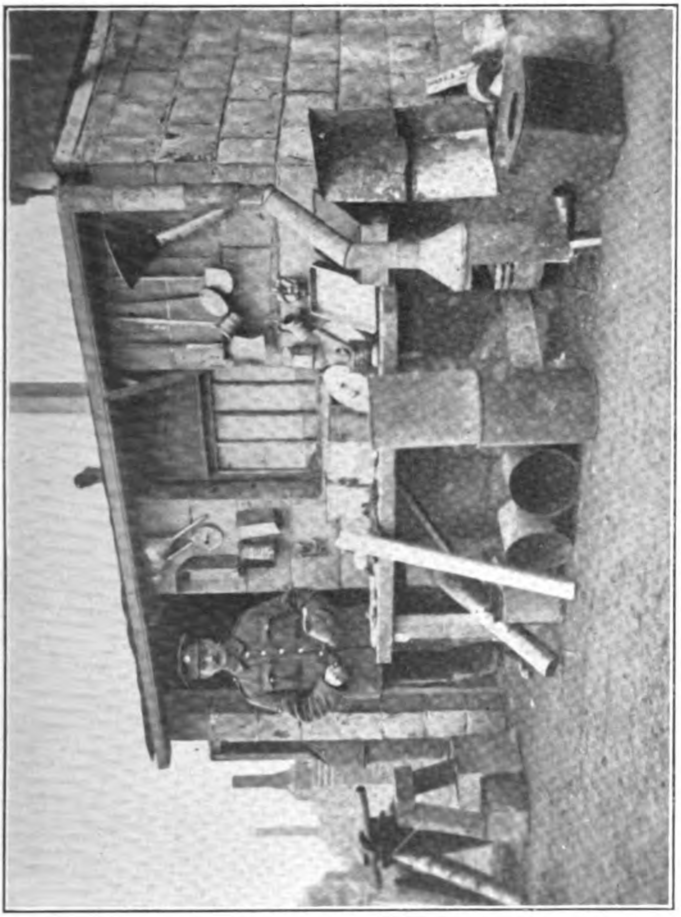

Fig. 6.—Hut and sanitary appliances constructed from waste material.

Clothing and equipment for every front were displayed, and three dummy figures, equipped for service in the Eastern, the Western and the North Russian fronts, demonstrated the method of wearing the clothing issued.

In the food section, among other things, were exhibited

foods for preventing beri-beri, germinating cereals, blown tins of various sorts and hay boxes for trench or billet.

A room was devoted to tropical work, and included mosquito nets, mosquito-proof bivouacs and other appliances specially devised for the tropics.

Fig. 7.—Hut and sanitary appliances constructed from waste material.

In addition to the exhibits, files were kept, in which were summarised all the orders, circulars and memoranda dealing with sanitary matters issued for the various fronts up to date.

The field exhibition was divided into a western, an eastern, and a trench area. The western area was divided into seven sections, and, as far as possible, showed every type of sanitary

appliance used on the Western front. Innumerable variations had been invented, types were constantly "improved" or modified, but still the main principles remained. As far as possible the examples exhibited could be said to represent standard types upon which modifications could be based. (Figs. 4 and 5.)

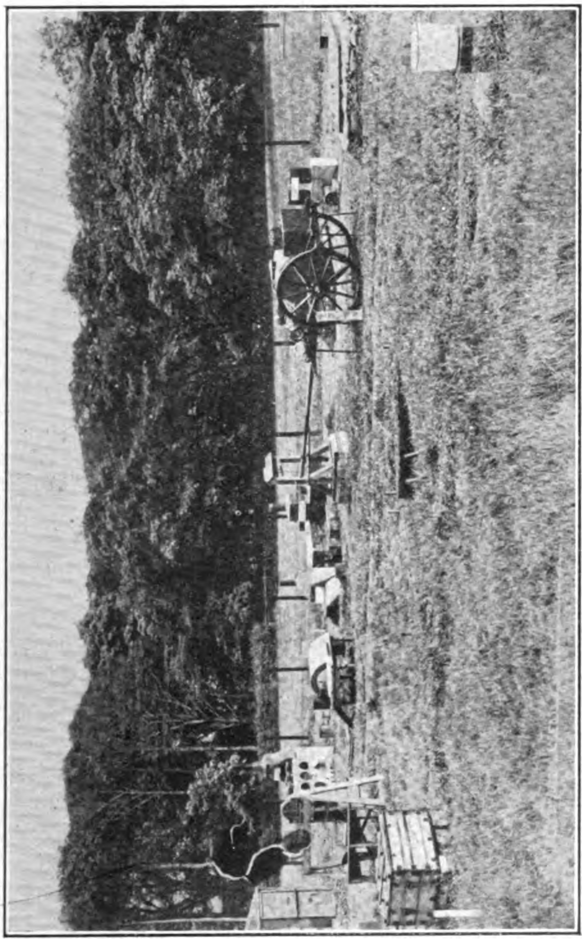

Fig. 8.—General view of water and cookhouse sections.

The first section of this area was devoted to improvisation, exemplifying how waste material could be used for sanitary work. A hut constructed entirely of waste tins contained apparatus of every kind, bunks, stoves, etc., made from scrap material. (Figs. 6 and 7.)

The second section exhibited a model cookhouse with contents (Fig. 8); field ovens, grease traps, etc. (Fig. 9).

The third section was devoted to water supplies, and showed wells, water-carts, improvised chlorinators, etc.

Fig. 9.—Field ovens and grease trap.

The fourth section illustrated types of destructors from the simple turf incinerator to the Horsfall, covering all the main points in construction and management. Manure incinerators were also included. (Figs. 10–12).

The fifth section dealt with latrines and sewage disposal (Fig. 13). Shallow trench latrines, deep pit latrines and receptacle latrines were shown, with examples of bad types (Fig. 14). A model urine pit (Fig. 15), with various types of trough, was included in this group. To cover the training

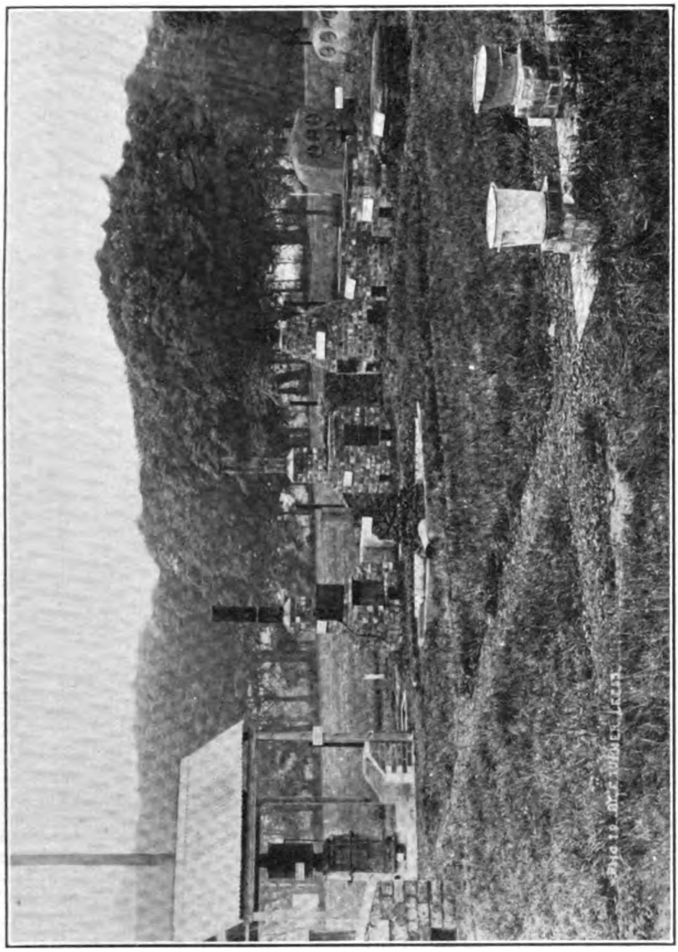

Fig. 10.—General view of incinerator section.

for home camps, a complete drainage system (Fig. 16) was installed, and a model sewage disposal scheme (Fig. 17) with sedimentation tanks and filters. "Herring-bone" and other systems for surface disposal were also shown.

The sixth section was devoted to disinfection and disinfestation, and included a dugout hot-air chamber (Fig. 18), Thresh disinfector, a field sterilizing box, and a portable box disinfector (Fig. 19). In association with this section a "Washington Lyon" disinfector was also demonstrated.

Fig. 11.—View of the incinerator section.

The seventh section was devoted to questions of ablution and sullage water disposal (Fig. 20). A special tank for the treatment of sullage water with bleaching powder, lime or acid

sodium sulphate was constructed. An improvised shower-bath and system of disposal pits were also shown.

The Eastern area was arranged in a similar manner, but contained appliances specially applicable to Eastern conditions:

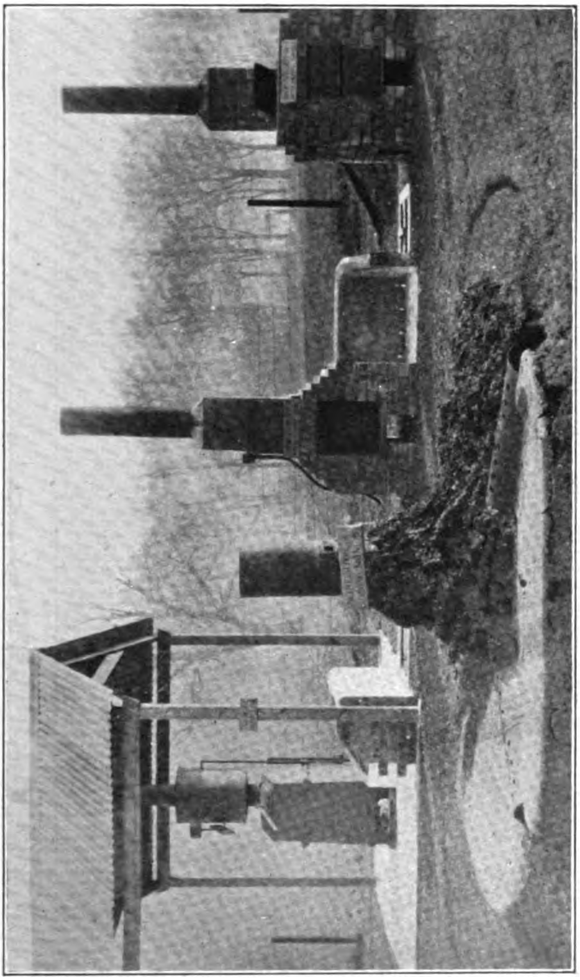

Fig. 12.—View of the incinerator section.

clay ovens (Fig. 21), cold storage chambers, a dugout larder (Fig. 22), Serbian barrels for disinfection (Fig. 23), native latrines (Fig. 24), fly-traps (Fig. 25), and so on.

The trench area was occupied by a small section of trenches,

as seen on the Western front, which included a front line trench with pit latrines, receptacle latrines, dugouts with rat-proof food safes (Fig. 26), refuse receptacles, etc., also a communication trench and an abandoned side trench with refuse disposal area.

Fig. 13.—General view of conservancy section.

At the conclusion of the lectures and demonstrations the American officers were taken to a camp where they could see the various details of sanitary work actually carried out. There is, of course, no finality to such a scheme of visual training, but the above summary indicates the lines upon which such work can be undertaken. Demonstration camps and

centres were much used during the war and their utility fully justified their existence.

Non-commissioned officers and men destined for sanitary work at home and abroad were also trained at the Leeds school. A course of lectures was given on the theory and practice

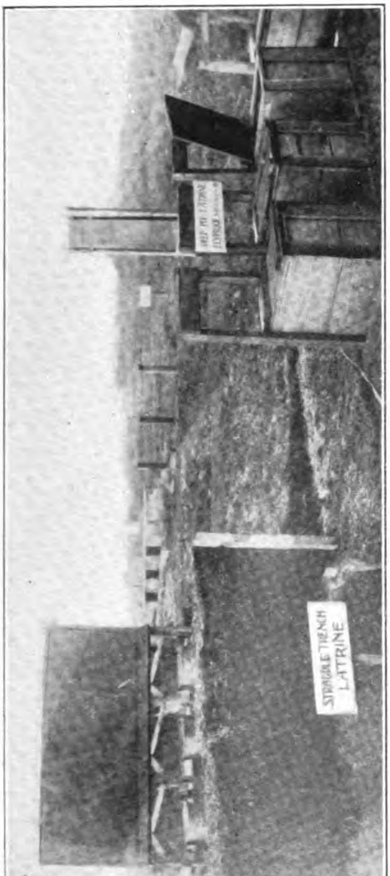

Fig. 14.—Straddle trench and deep pit latrines.

of sanitation in the field, with demonstrations of the various processes employed. These lectures followed the usual scheme of the medical officers' course. They were more elementary in theory, but more detailed in practice. All details of construction of sanitary structures were taught practically, and in addition every man received instruction in elementary brickwork, woodwork, metal-work and drawing. Three days were devoted to each of these subjects and at the end of the

course a written and practical examination was held. In addition to this examination, small *viva voce* classes were conducted each day and notebooks were inspected, a method which

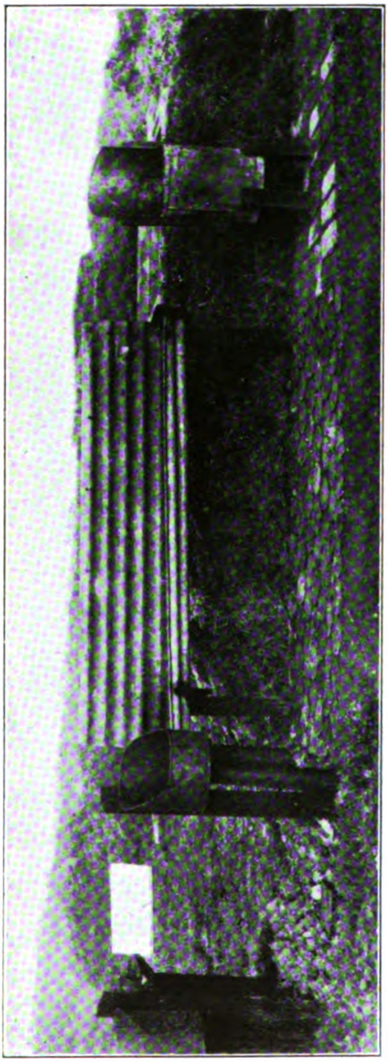

Fig. 15.—Urine pit.

was of much value in estimating the attention paid to lectures and demonstrations by each individual. The course had to be a very hurried one, but five or six weeks were sufficient to give an intelligent man a grasp of the main essentials of the work.

The staff of the school consisted of one officer (a sanitary specialist who had served on the Western front), one sergeant (an expert builder and sanitary inspector), one corporal (an old soldier who was expert at metal-work), one lance-corporal

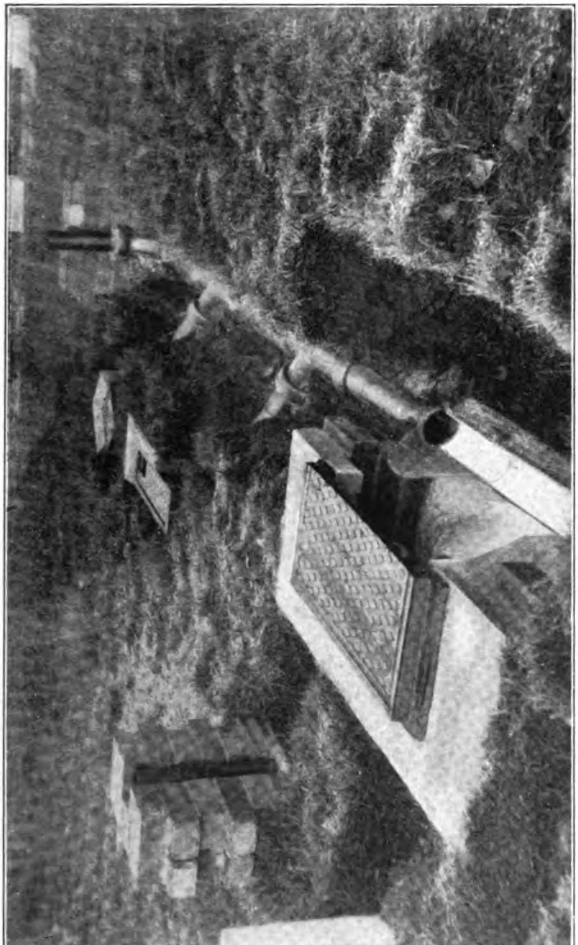

Fig. 16.—Model drainage system for demonstration purposes.

(a carpenter), four privates (a builder, an architect, an artist, and a clerk). In addition there was a fatigue party which varied in number from eight to twelve.

In addition to the classes mentioned, men were trained so that they could form a nucleus for the establishment of similar

schools, and special classes were held for various British officers who came to the school for instruction.

The Royal Army Medical Corps School of Hygiene, Blackpool.—Of necessity the Leeds school could only be regarded as a temporary war-time measure, and a more complete permanent school of hygiene was subsequently established at

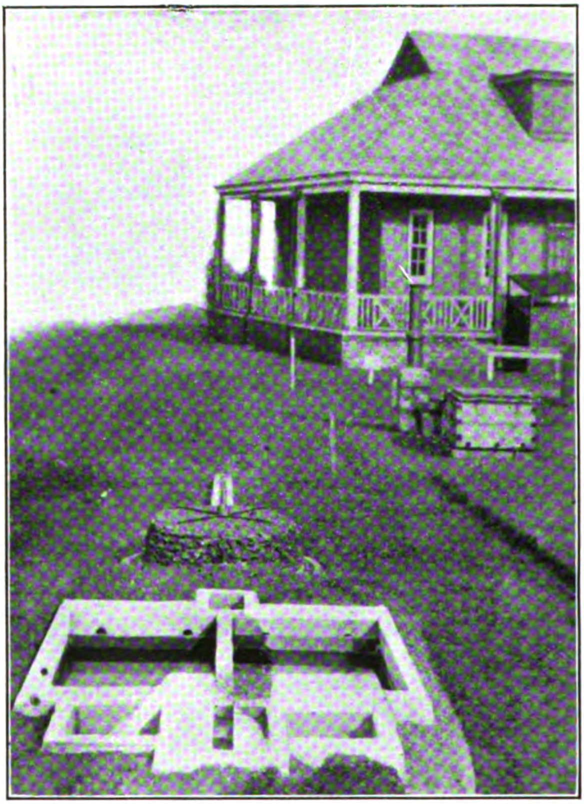

Fig. 17.—Model sewage disposal system.

Blackpool, where for some time an excellent course in field sanitation and tropical medicine was included in the training for Royal Army Medical Corps officers.*

This school was established in response to the urgent demand for specialized training in preventive work, more especially for

* See p. 156, Vol. I, Medical Services, General History.

medical officers selected for work in the tropics. It was designed on ambitious lines so that all types of preventive work, both elementary and advanced, could be taught. Medical officers of all grades received instruction in tropical medicine,

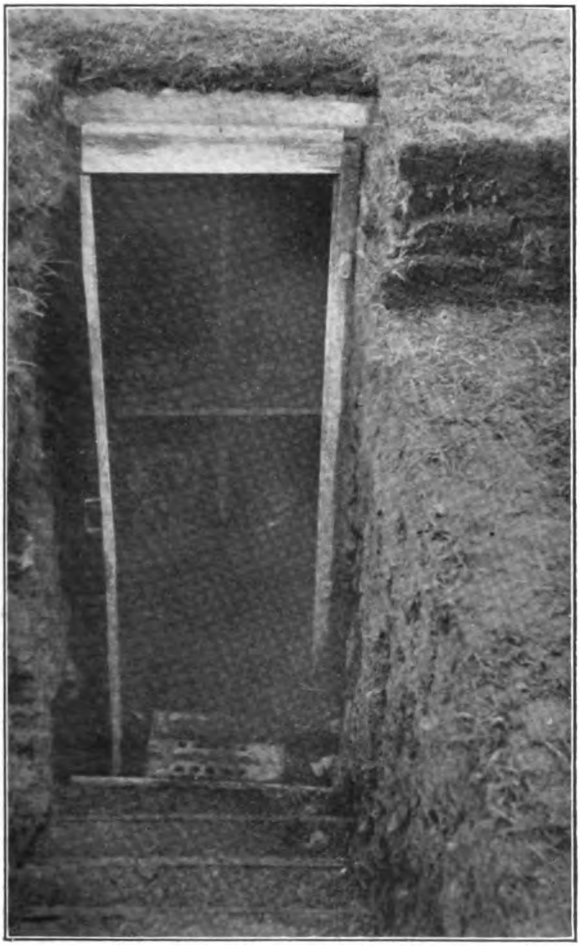

Fig. 18.—Dugout hot air disinfestor.

both from a clinical and prophylactic point of view; they were also taught the general principles and practice of hygiene, including practical bacteriology and the analysis of food and water. Apparatus of all sorts were demonstrated, and

there was an exhibition on similar lines to the one at Leeds, but in a more advanced stage of evolution.

In addition to the classes for medical officers, there were

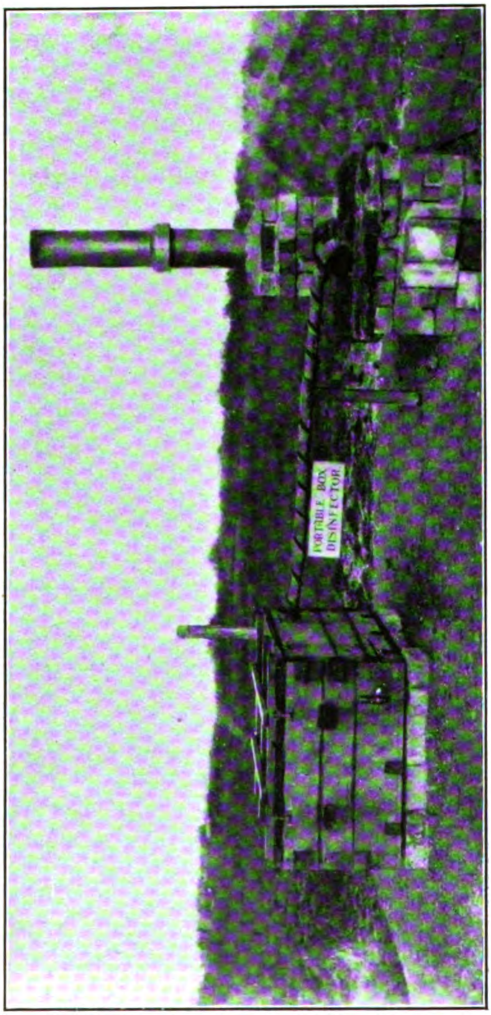

Fig. 19.—Portable box disinfector.

others for non-commissioned officers and men who were selected for special sanitary work.

A précis of the subjects of the officers' course is given in Appendix A, 1. A lecture lasted about two hours, and practical

classes about three hours. All lectures were illustrated by demonstration of specimens, charts, etc.

The course of instruction occupied six weeks ; when necessary it was reduced to one month by lessening the practical work

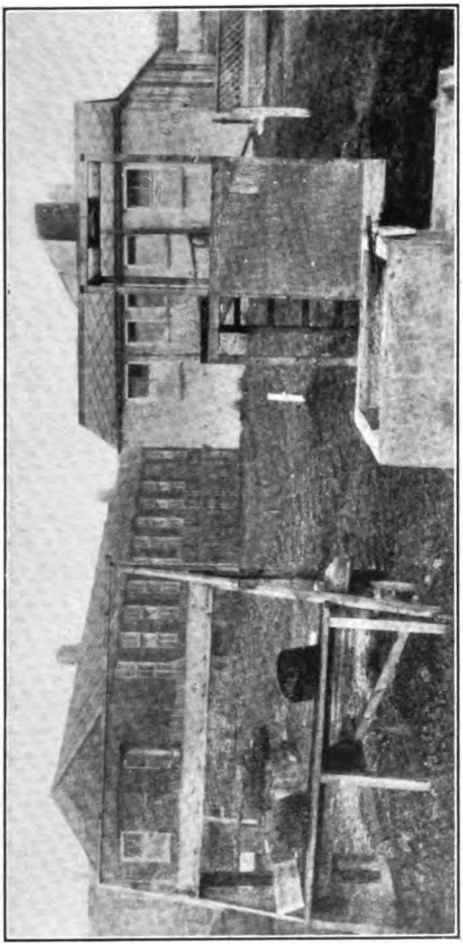

Fig. 20.—Ablution section.

in bacteriological methods of diagnosis and in chemical investigation of foods.

Appendix A, 1, also gives a précis of the subjects dealt with in the men's course. This centre may be summarized as a school for teaching tropical medicine and hygiene, with special

application to the demands of military life, and for special training in general army sanitation. The syllabus illustrates well the scope of preventive medicine during a war of world-wide extent.

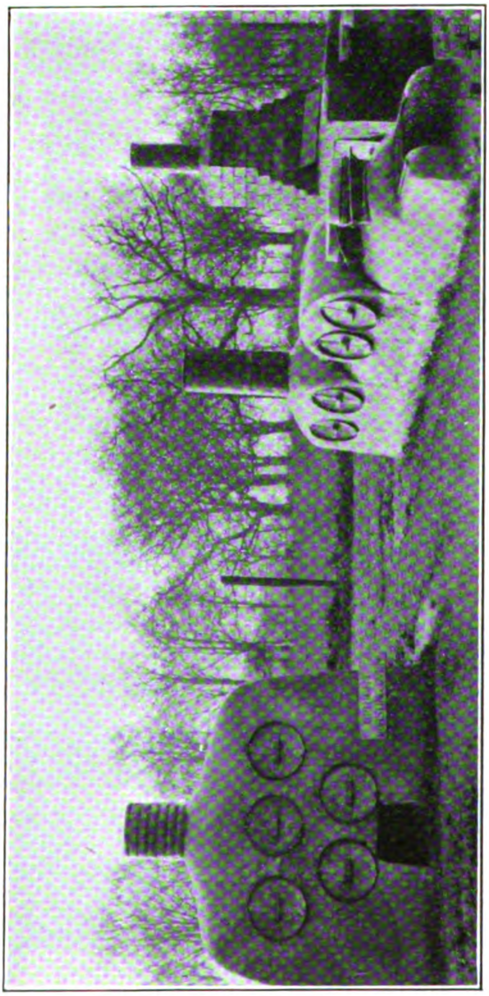

Fig. 21.—Clay ovens in the East.

Courses of Instruction in Commands.—In addition to established schools, courses of instruction were provided in many commands. These included lectures and demonstrations, and were of service in bringing before the notice

of combatant, as well as medical officers, the scope and importance of sanitation in military life. The general scheme of such a course may be gathered from a description of the classes in hygiene held in the Eastern Command.

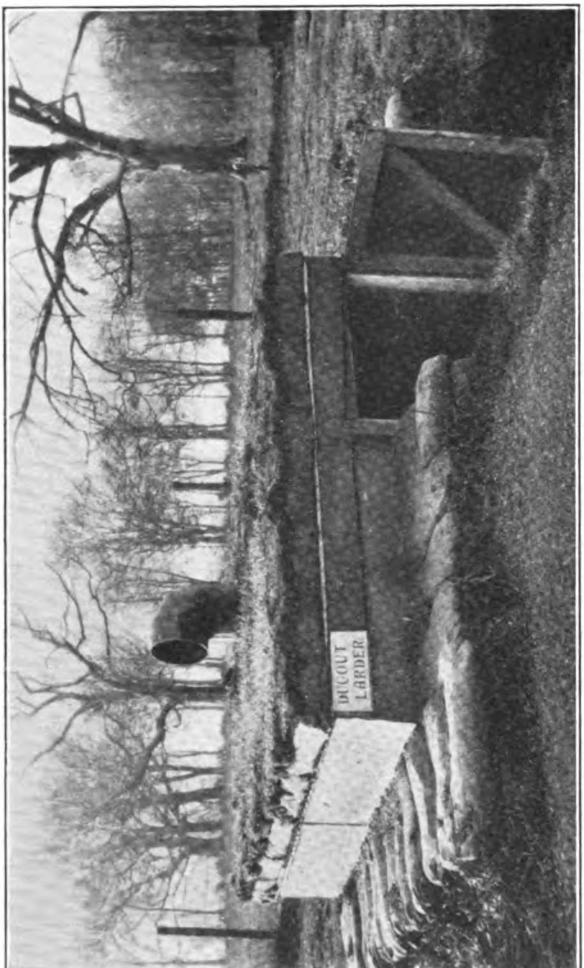

Fig. 22.—A dugout larder.

These classes were commenced in September 1917, on instructions from the War Office. At first the classes lasted a day and a half each; later it was found desirable to extend

them over two days, and finally each class lasted for two and a half days.

An effort was made, with some success, to get officers second-in-command, quartermasters, and other more responsible officers to attend. A means to this end was the holding of

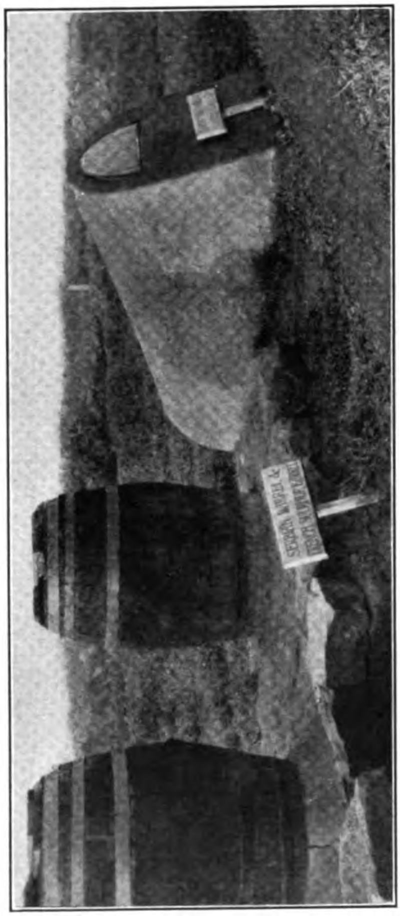

Fig. 23.—Serbian barrels.

the classes towards the end of the week. For the first year the classes were held partly at the headquarters of the Royal Sanitary Institute, the directors of which, in addition to other valuable assistance, placed their lecture theatre, lantern, museum and some of their staff at the disposal of the Command

Sanitary Officer, free of charge. Lectures were also given at the Royal Army Medical College. Thirty to forty officers attended each class.

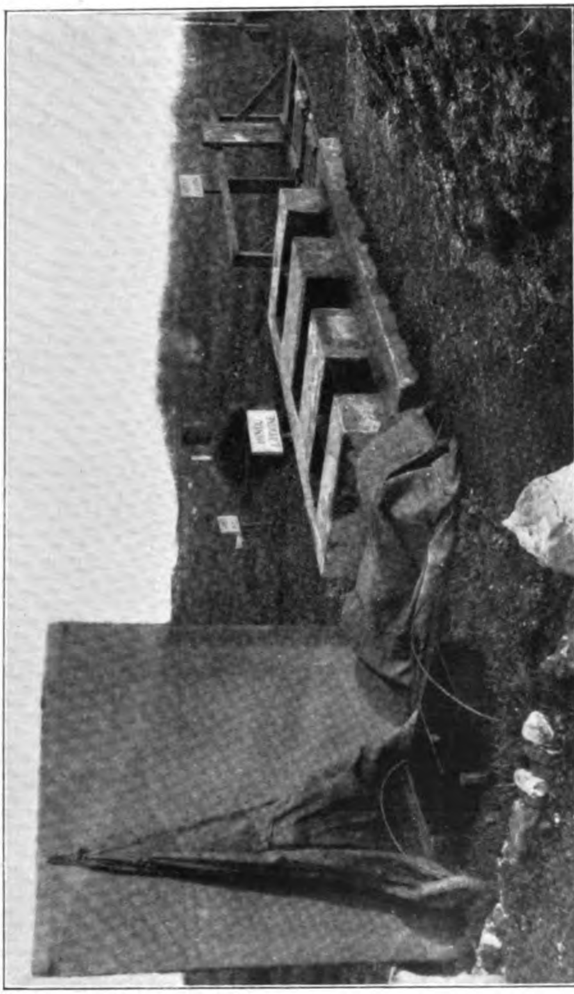

Fig. 24.—Native latrine.

Out-of-door demonstrations were given at the Duke of York's headquarters, and at Manor Street, Chelsea. The models used were originally made by the London Sanitary Companies. They were afterwards considerably improved

and augmented under the directions of the D.D.M.S. of the command.

One lecture was given on general hygiene, with special reference to the mode of spread and the means of preventing infectious diseases; two on insects in relation to disease, one of which dealt with biting insects, the other with non-biting insects; and there was a lecture on the sources and means of purification of water supplies.

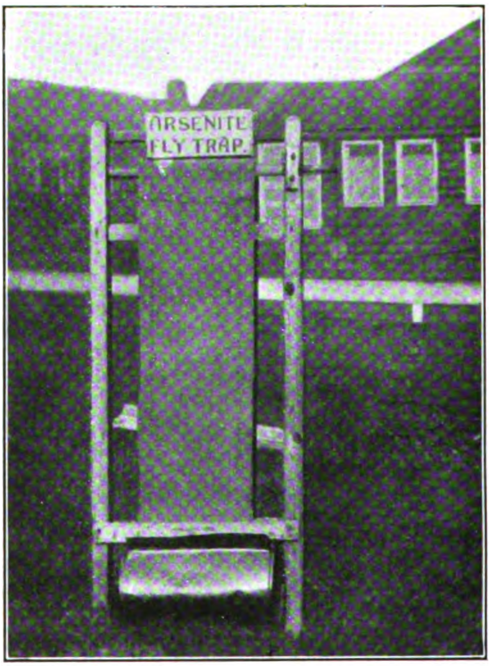

Fig. 25.—Arsenite fly-trap.

All these lectures were illustrated by lantern slides. Some of these slides were prepared by the Royal Army Medical College, others were specially prepared from designs made at the Headquarters, Eastern Command.

Two additional lectures were given, one on food, illustrated by diagrams and later by models supplied by the late Professor Sir W. H. Thompson, of the Ministry of Food, and another on tropical hygiene. The latter was always given

by an officer who had had experience of service in the tropics.

In the later days of the war it was intended to establish schools of sanitation in all commands, and all preliminaries were carried out, but at the time of the armistice the scheme was not in full working order.

Fig. 26.—Dugout in the trenches with rat-proof safes.

Special Training.

Many branches of sanitation required special training. The sanitary officer could not be expected to be a specialist in every branch of sanitary work, engineering, water supplies, sewage disposal, dietetics, entomology, bacteriology, chemistry, statistics, and this was true to a much greater extent in the case of the sanitary assistant or inspector. It was recognized that the place for such training was not in the schools of sanitation, but where individual personal experience of the working as actually carried out could be obtained. For example, it was only by actual experience with the water column that full knowledge of the methods of chlorination and apparatus required could be gained, so as to enable the specialist in water purification to undertake definite responsibility. The same may be said with regard to specialization in mosquito work, surveys, drainage, and so forth. A certain amount might be learned by hearing lectures, examining dried specimens, looking at models and photographs, but it was only by definite training in field work, in mosquito collection, mosquito breeding, and general practical experience under a skilled entomologist that efficiency could be acquired. The importance of this specialized education was appreciated during the war, and an ever-increasing effort was made to satisfy the demand.

At Brentford, where much ground had been covered with regard to chlorination on a large scale, men received practical instruction in the work of a water column; here they were able to follow the whole process and carry it out under the supervision of an officer whose experience in this branch of work was unique.

At Sandwich the War Office established an Entomological School, with every facility for carrying out special work. The locality was suitable for the field collection of mosquitoes and all appliances required for further research, such as breeding ponds, mosquito cages, constant temperature rooms, were supplied. Here officers and men were able to familiarize themselves with all the up-to-date methods and requirements of such work under the supervision and instruction of a skilled entomologist.

In the Southern Command, where the work of incineration had reached a high stage of perfection owing to the enthusiasm and skill of those in charge of it, many men received an unrivalled practical experience in this branch of sanitation.

In the wider field of sanitary administration the need of

training was increasingly acknowledged, so that men of tried experience in civilian work were given opportunities of acquiring knowledge in sanitary administration, as applied to military life, before assuming posts of responsibility. This was not always recognized during the war, and occasions arose when civilian medical officers of health, ignorant of the practical application of their work to military conditions, were placed in positions of authority over the heads of men who had made a lifelong study of military hygiene. Such anomalies were bound to lead to inefficiency and discontent, and it was clearly essential that every civilian medical officer of health should be fully instructed in the military application of his sanitary principles before he was placed in a position of authority in the field.

There were always certain centres where special work could best be seen and the details learned with the greatest rapidity; time given up to visiting such centres was well spent, in that it enabled full use to be made of past experience. Such special visits formed an important link in the chain of sanitary education.

Local Training.

After a man had completed his general training and, if necessary, his special training, he was in a position to be sent to the area where his sanitary work was to be carried out. This might be at home or abroad; if abroad, it might be in a western war area, where conditions approximated closely to those at home, or it might be to an eastern area, where an entirely new environment would be encountered. To fit him for work under such conditions, it was necessary for him to appreciate the difficulties with which he was likely to be faced, and the conveniences at hand for dealing with such difficulties. The nature of the country, the insect fauna, idiosyncrasies of the inhabitants, conditions of water supply, material available, difficulties of transport and many other problems had to be enquired into. On the Western front, though the conditions approximated more closely to those at home than in the east, still there were details to be learnt with regard to trench life in different areas, special orders, available material, and so on, which made it advisable for those engaged on sanitary work to supplement the knowledge already obtained. This was absolutely essential so far as the eastern theatres of war were concerned, and to satisfy this need demonstration centres were established at the various bases, where all men and officers

passing through could quickly learn the special dangers to which they would be exposed, and the various methods which had been found available and suitable to overcome them.

In many places in the east such centres were established largely owing to the energy of a sanitary section officer with special knowledge of educational methods, and through these centres medical officers, staff officers, regimental officers, and other ranks passed on their way to the front and were taught how to avoid dangers which, without such fore-knowledge, must have seriously diminished their fighting value. Here they were informed what material would be available for sanitary purposes; they could see how such material could best be used for sanitary purposes; they could be shown the improvised apparatus at work and study details of construction and management. Nine such schools were established in Egypt and Mesopotamia alone. Full-sized working models were shown of every conceivable type of sanitary apparatus, and demonstrations were given. It was essential to make such courses short and graphic, but the demonstrations were of special value in widening the outlook with regard to sanitation, and teaching how much could be done by improvization. In France, also, these local schools and demonstration centres were no less prominent. One amongst many, a school started in the winter of 1916 at St. Pol, will serve as a type. In 1917, an officer from the 2nd London Sanitary Company was appointed commandant, and the school was developed on progressive lines. Models and sanitary appliances of all sorts were installed and lectures and demonstrations given daily. The teaching staff consisted of the D.A.D.M.S., Sanitation, the officer commanding a mobile hygiene laboratory, the officer commanding a sanitary section, the officer commanding a mobile bacteriological laboratory, and the commandant, assisted by four non-commissioned officers from a sanitary section, which had had considerable experience of front line work.

All classes also received lectures and practical demonstrations on personal hygiene. At the close of each course a short examination was held, and certificates of proficiency were given where merited.

Two courses of three days each were open to officers each week, one for medical officers, and the other for regimental officers.

These courses included lectures upon the duties of officers in the field with regard to sanitary matters, lectures on water supplies and purification, disinfection and field sanitation in

general, with practical demonstrations of methods of construction and management.

Special courses were also given for American troops and for Indian labour units.

The school consisted of an indoor and outdoor exhibit, and working models of practically every type of sanitary appliance were shown. In addition, there was a small reference library.

Practically everything was improvised, an impressive object lesson for men who knew they would be called upon to carry out their sanitary work with a very inadequate supply of orthodox material.

By means of such a school the fundamental lessons learnt in the United Kingdom received their applications to special conditions, and a uniform standard of sanitation was provided for each district.

Revision Courses in the Field.

For many reasons it was important that sanitary teaching should be carried further forward than the base. In the front line settled conditions gave place to an ebb and flow, which menaced all hope of continuity ; men were killed or invalided to the base, they were replaced from other less essential branches, or from drafts hurriedly supplied. Intelligent sanitary men in a battalion might be replaced by men who were incompetent or physically unfit, and water-duty men were often utilized for other work. This was undoubtedly a bad policy, but the military necessity during severe fighting overruled sanitary requirements.

Revision work was conveniently carried on behind the front line during periods of rest. Classes were arranged at various centres, and all sanitary or water-duty men were ordered to attend. By this means it was possible for the sanitary officer on the staff of an A.D.M.S. of a division to keep in touch with those directly responsible for executive sanitation, and to have some check upon the continuity of the battalion sanitary personnel. At these classes all sanitary matters were reviewed practically, and with an eye to special local conditions. Separate classes were held for water-duty men and sanitary personnel, and the former were specially instructed in the care and use of the water-cart and the performance of the test for chlorination. These revision classes were also valuable in encouraging the men in

their work, and it was easy for a keen lecturer to stimulate enthusiasm.

Special classes were also held to meet any emergency which might arise. For example, a water class was held in a barn, before one of the great British offensives, to instruct the water-duty men of the division in an improvised system of chlorination for tanks, which had been placed in the trenches to meet any emergency during the attack and preliminary bombardment.

Revision classes for officers were equally important, and were frequently held in temporary schools in close proximity to the line. The value of models, however small and crude, can scarcely be over-estimated, and many of the revision classes owed much of their success to the fact that all important points were illustrated by small hand models, which could be easily transported from centre to centre.

The commanding officers of battalions were not included in such classes, but it was extremely important that they should be kept in touch with new methods, and occasionally reminded of their sanitary responsibilities. To meet this need, an experiment was tried which might have been extended with considerable benefit. Under divisional orders in one division the commanding officers attended a conference where a short dissertation was given on preventive work, in so far as it specially affected them. At the end of the lecture there was a discussion upon the various difficulties which presented themselves with regard to the work.

Popular Lectures and Propaganda.

There was much scope for propaganda work of a popular type with regard to measures for the preservation of health. Popular lectures and posters were invaluable. Picture post-cards, posters, and leaflets were freely used to enlighten the soldier with regard to the danger of flies, mosquitoes, and other insects, also in order to impress upon him the need for strict obedience in carrying out orders with regard to sanitation, quinine prophylaxis, and so on. The object of these was to enlist active co-operation by appealing to the men's common sense. A certain degree of "abandon" in this branch of teaching was an excellent thing; a louse of normal dimensions may be sufficient to stimulate the work of the scientist, but to impress the men it was necessary to paint it in lurid colours and of gigantic proportions. The French malaria propaganda posters were specially well designed in this respect.

Sanitary Discipline.

The best lesson of all in sanitary matters is the practical lesson of daily experience. Too much stress cannot be laid upon the value of example and strict discipline, so that the men automatically carry out the precepts they have been taught. On many occasions, the billets occupied by sanitary personnel were found defective in sanitary details of cleanliness and order. It was hopeless for an orderly officer to expect the company's cookhouse to be properly managed if the cookhouse of the officers' mess was neglected. The commanding officer, adjutant and orderly officer had, therefore, to emphasize the importance attaching to sanitation by practice as well as by precept and by a strict attention to detail, so that from constant repetition, habits of cleanliness became automatic amongst the troops under their command. It was only by the establishment of a sanitary conscience in a unit that danger could be avoided at times when the mind was distracted by more pressing matters. To maintain this high standard under active service conditions, routine inspections by men especially trained for the purpose were of great value.

CHAPTER III.

PURIFICATION OF WATER.

THE provision of a safe drinking water for the troops in the field was always regarded as a matter of the first importance, and, following on the experiences during the South African war, considerable attention had been given to the subject at the School of Sanitation, Aldershot. Methods for the purification of water suitable for the use of troops on active service were closely studied there, as well as at the Royal Army Medical College.

Experimental Work prior to the War.

Up to 1908 the purification of water on field service was being effected by the filtration of water through earthenware candles, after preliminary clarification of the water through compressed sponges. The field service filter tank supplied to units consisted of an iron tank holding 110 gallons, mounted on two wheels. It was fitted with two pumps and two clarifying filters, and for sterilizing purposes eight filter tubes were arranged in two batteries of four each. There was a small 7-gallon tank at the back of the main tank which received the sterilized water, and fitted to this and to tubes running along each side of the main tank were twelve taps at which water bottles were to be filled.

The main tank carried water which was supposed to be freed from coarse suspended matter by being passed through the clarifying filters. These consisted of compressed coarse sponges placed in two horizontal cylinders on each side at the top of the hinder part of the large tank.

The clarified water in the main tank was pumped through the eight filter tubes, and each filter tube had its own delivery tube, or "swan-neck." It was considered better to have eight separate tubes than two large filters, as an alteration of the rate of delivery from any one of the filter tubes would give immediate evidence of defect, and show which filter was defective; and for a similar reason the tubes were made to discharge into the open.

A store of sterilized water was not carried, except the water that might be in the 7-gallon tank placed behind the main tank. Both tanks were readily accessible for special cleansing.

A very short experience of this tank showed that the passage of water through compressed sponges was not an efficient method of removing fine particulate matter suspended in it, and attempts to pump this water through the candles caused a rapid blocking of the filtering material and a corresponding rise of pressure, which eventually resulted in a breakdown of the pumps. In order to obtain better clarification a clarifying cylinder was designed by Colonel Horrocks. The cylinder contained a cylindrical reel round which several layers of flannelette were wrapped; to the head of the cylinder was fixed a perforated box which, when the head was screwed up, forced the spigot of the reel into the outlet from the cylinder, a watertight joint being made with a rubber ring. The outlet from the cylinder was branched; one branch was fitted with a tap, the other passed at a higher level into the body of the water-cart. Alum was placed in the box and was dissolved by water pumped through the perforations in the sides of the box; the alumed water passed to the outer side of the reel, and a layer of coagulated suspended material was gradually formed on the surface of the flannelette, which then acted as an efficient clarifier. The tap on the outlet pipe from the cylinder was left open until the water issuing was quite clear; the tap was then closed and the water directed into the body of the cart. A number of the water tanks were fitted with this clarifying apparatus in place of the compressed sponges, and when the water tanks were in charge of well-trained R.A.M.C. men the results were fairly satisfactory. The well-clarified water was pumped through the earthenware candles with very little increase in pressure beyond that required from the passage of water through the filtering material. Road trials demonstrated that the balance of the 1908 water tank was unsatisfactory; the dome-shaped tank being placed above the axle, there was a great tendency for the tank to turn over when driven rapidly round sharp bends on a road. A cylindrical tank, with as much of the body as road clearance would permit being placed below a horizontal line passing through the centre of the wheels, was suggested. This suggestion was approved, and several new cylindrical tanks, fitted with the new clarifier and filter candles, were constructed; these carts were known as Mark III.

From a transport point of view the new tank proved satisfactory, but doubts were entertained whether it or the dome-shaped tank would survive the strain of field service. It was thought that any filtering apparatus depending for its efficiency

on earthenware filter candles would inevitably break down; even supposing that the candles themselves were free from flaws, which was extremely doubtful, unless each one were bacteriologically tested, a physical impossibility, considering the number likely to be required. The fact that each candle in the battery must have a microbe-tight joint, and each candle must be removed and sterilized at least once a week, seemed fatal to the efficiency of the cart on field service. Attention was therefore directed to the sterilization of water, after preliminary clarification, by means of chemicals. In view of the probable failure of filter candles on active service numerous experiments were carried out at the Royal Army Medical College on the sterilization of clarified water by means of active chlorine obtained from chloride of lime, and as a result of these it was ascertained that most well-clarified waters could be rendered innocuous by 1 part of active chlorine per 1,000,000 acting for a minimum period of half an hour. The adoption of a new field service water-cart was therefore suggested. The cart was to have a cylindrical tank and two large clarifiers, similar in type to those already described. The clarified water, usually about 110 gallons, would then be treated with sufficient chloride of lime to produce 1 part of available chlorine in 1,000,000 parts of the water. It was considered essential for field service purposes that the clarifiers should have a surface sufficiently large to enable the water-cart to be filled without the necessity of changing the flannelette on the reel.

In the first clarifier attached to the water tank provided with filter candles, the size of the reel was determined by the measurements of the cylinder containing the sponges; the clarifying surface so obtained, whilst sufficient to remove the suspended matter from many waters, did not suffice when the water contained a good deal of mud. In these circumstances it was occasionally necessary, before the cart was filled, to remove the flannelette and substitute a clean sheet, which was carried on the tank for this purpose. If attempts were made to pump water through the flannelette when heavily coated, either the cage collapsed or the suspended matter was driven through the material, and it was found necessary to put a release valve on the cylinder to relieve the pressure when the danger point was approaching.

A water-cart known as Mark IV, embodying these principles, was then constructed. It consisted of a body holding about 110 gallons, a large clarifier of standard type attached to each

side of the tank, and two pumps designed by the Carriage Department of the Royal Arsenal at Woolwich. Very good results were obtained, but experience showed that flannelette was not a suitable material for prolonged use; when washed it shrank too much, and was readily torn. Further experiments were then made, and eventually a closely woven cloth was obtained which suited the purpose admirably, and was generally adopted for use with the clarifiers.

The cylinder of the Mark IV cart was placed with the long axis running from front to rear; road trials showed that with this arrangement there was too much strain on the horses when the cart was being taken up or down a road with a sharp gradient. It was then suggested that the long axis of the cylinder should be placed transversely between the wheels. In this way the movement of water in the body of the cart was much reduced and the strain on the horses largely obviated. This type of cart was known as Mark V.

Further experience with the new tank showed that there was a tendency for the men, unless carefully watched, to pump imperfectly clarified water into the tank. As in these circumstances 1 in 1,000,000 of free chlorine acting for half an hour might not destroy all the microbes causing water-borne disease, some of the free chlorine being taken up by the organic matter, orders were issued that a trace of free chlorine must be present in the water drawn from the cart at the end of the half-hour required to fill the cart. Samples of water from the tank were to be withdrawn at frequent intervals and tested with a solution of potassium iodide and starch. If the presence of free chlorine was not detected then, more chloride of lime was to be added until free chlorine was maintained in the water for the requisite period. A clarifying cylinder, with hose and pumps, was packed in a box and issued to small units and messes. This portable "box clarifier" was also used in circumstances where tanks could not be employed.

A simple and effective process by which units on the move could be provided with clear, safe water seemed now to have been devised, and it was hoped to test the new water tanks on the manœuvres to be held in the summer of 1914. Unfortunately, war was declared, and the new tanks could not be tested beforehand under service conditions.

Various designs of apparatus for the sterilization of water by means of heat were also examined. Most of these were designed on the heat exchange principle. This, applied to the purification of water, depends on the fact that, with a

sufficient area of metallic surface of good conducting capacity and with sufficient time a given quantity of liquid will yield nearly all its heat to an equal volume of the same liquid. The incoming cold water is made to receive heat from the outgoing hot water, and in this way the double advantage is gained that the amount of fuel necessary to raise the water to the required temperature is much lessened, and the water issuing from the apparatus is almost as cold as that originally supplied. The greater number of the apparatus examined failed to be either sufficiently portable or to yield sufficient sterilized water in proportion to their size and weight. The apparatus which found most favour at the School of Sanitation was known as the "Griffith." The novelty in this sterilizer was the recognition of the fact that a momentary exposure of water to a temperature of 180° F. was sufficient to destroy all disease-producing germs that are conveyed commonly by water. The vital part of the apparatus was a valve which controlled the passage of the water from the sterilizing chamber to the cooler. The valve is immersed in the water which is being heated and is so made that it opens only when the surrounding water attains a temperature of 180° F., or 81° C., and closes automatically when this temperature is not maintained. Up to the year 1914 portable sterilizers on the heat exchange principle suitable for troops on the move had not yet passed the experimental stage. The size, weight, and limited portability of these sterilizers restricted their use to fixed points. Even if employed for fixed water points, a good motor pump would be required and some means of removing suspended matter, such as a sand filter, would have to be provided. The fuel required for the sterilization of large quantities of water would be considerable and add to the difficulties of supply.

Measures taken in August 1914.

A careful study of the sources of supply likely to be available for the troops had been made previous to the declaration of war. The Director of the Geological Survey, Sir Aubrey Strahan, had been consulted, and supplied most useful general notes on the sources of temporary water supplies in the South of England and neighbouring parts of the Continent, also many maps illustrating the geological conditions of the areas in which British troops were likely to operate. The Institute of Civil Engineers also placed their valuable library at the disposal of the War Office, and the reports of some of the leading experts on the water supply in Belgium and North-east France were

studied. From these enquiries it was quite clear that in Flanders, as far as the ridge geologically dividing France from Belgium, the chalk was not water-bearing, and that below the chalk the water obtained was unfit for drinking. In this area troops could therefore only be supplied with surface water from either canals, ponds, streams, or shallow wells, and in a few cases from springs, and such water would invariably be contaminated. South of a line running through Boulogne, Aire, and Valenciennes, water-bearing chalk might generally be found at varying depths; a number of artesian wells existed, but whether additional borings to meet military requirements could be made with the necessary speed seemed open to question.

In these circumstances it was evident that water for drinking purposes would in many cases require clarification and in all cases should be sterilized as far as possible before issue to the troops. All medical officers were instructed that the quickest and safest method of sterilizing water was by treatment with chloride of lime. They were informed that 23 grains of chloride of lime would sterilize 100 gallons of clear water for all practical purposes in half an hour, and that if the water contained much suspended matter it must be removed by alum, 3 grains to the gallon, before chlorine treatment was commenced. The chloride of lime issued contained an average of 30 per cent. available chlorine, so that 23 grains of chloride of lime per 100 gallons ensured that the water received approximately 1 per 1,000,000 of available chlorine.

Steps were taken to issue to all units chloride of lime in 4-oz. tins each containing a spoon, holding 23 grains, fastened to the lid. But before these could be obtained chloride of lime in the ordinary packs was sent to France and the troops were informed that a half-penny held between the fingers and dipped into a tin of chloride of lime would just carry the amount required for 100 gallons of water and that three-quarters of an inch of the blade of the regulation clasp-knife, measured from the point, carried the same amount of chloride of lime.

As most of the water tanks in possession of the units of the first divisions which proceeded to France were of the Mark I type containing sponge clarifiers and filter candles, each medical officer of a unit was instructed that, if the candles became inefficient through blockage or breakage, 23 grains of chloride of lime should be added to the 100 gallons of water contained in the tank. A few weeks later medical officers were requested to chlorinate the water in the water tanks in all cases and to place no reliance on the filter candles.

It was also decided to furnish all new units with water tanks provided with a large clarifying apparatus and to trust entirely to chlorination, after clarification, of all water supplied to troops. Full working instructions were issued with each water tank. Owing to difficulties of supply the cylindrical tanks (Mark V) could not be obtained in sufficient number and some of the square tanks with dome-shaped tops had to be issued for a time. The clarifying cylinder, a pump supported on a tripod and necessary hose pipes were also packed in a box and issued as a portable clarifying apparatus. This was found very useful for small units. The water from the source of supply was pumped into a small portable tank and the clarified water was then chlorinated, the amount of chloride of lime required being determined by means of the test box.

In addition to water tanks, cavalry units were also supplied with bottles of acid sulphate of soda, each containing 16 grains of anhydrous sodium bisulphate and ¼ minim of oil of lemon.* Soldiers were instructed to dissolve one tablet, by stirring or shaking, in each pint of water used and to allow the water to stand for half an hour before drinking.

It was thought that cavalrymen might get separated from their units and be unable to replenish their water-bottles from the water tanks. By placing two tablets in the water-bottle and then filling it from a local supply each soldier could make sure of having in half an hour a practically safe water to drink.

In the first few months of the war it was felt that, if some simple process by which medical officers could determine the amount of chloride of lime required to render each water supply safe could be devised, it would be a great help. Most of the R.A.M.C. men detailed for water duty with units had been trained in the working of the Mark I tanks provided with filter candles, and there was little opportunity of training them in the procedure, simple though it was, of chlorinating water supplies; and the time which could be devoted to the training of new units was necessarily short. In 1914, Professor G. Sims Woodhead, of Cambridge, published a paper on the sterilization of water supplies for troops on active service. In this paper he stated, "I satisfied myself that if particulate matter could

* In May 1917, W. H. D. Dakin and Major Dunham suggested the use of tablets of halazone (P. sulphondichloraminobenzoic acid) for the sterilization of small quantities of water such as are needed by cavalry. Issues of the tablets were made to troops in several theatres of the war. The reports as to the sterilizing action of halazone were on the whole favourable, but some doubts were expressed as to its maintaining its efficiency under active service conditions, especially in the tropics.

be removed from a water by means of any of the ordinary filters, it was possible to render even a highly polluted water perfectly safe for drinking purposes by the addition of appropriate amounts of chlorine, and that these appropriate amounts could be determined by means of the iodine and starch test." Samples of the outfit recommended by Sims Woodhead were obtained and sent to France and to some of the divisions in the United Kingdom for trial. It was found that the testing outfit was useful in the hands of trained medical officers; but at that time it was almost impossible to supply in the quantities required for the field army glass tubes containing small weighed quantities of chloride of lime, and the troops were already in possession of chloride of lime packed in 4-oz. tins, each containing a standard spoon holding a definite quantity of chloride of lime.

A test case was accordingly devised which contained a graduated pipette, a standard spoon, one cup holding 250 c.c. of water, six cups containing 187 c.c. of water, and a test solution of zinc iodide and starch. The pipette was so graduated that one drop of a solution containing the contents of the standard spoon in 250 c.c. of water, when added to 187 c.c. of water to be tested, produced 1 part per million of free chlorine and one standard spoonful of chloride of lime in 110 gallons of water, the contents of the water-cart, produced approximately the same quantity of free chlorine in the contents of the cart. The method of using this test case is described in Appendix B, 1.

No difficulty was experienced in teaching N.C.Os. and men of both R.A.M.C. and regimental units how to use the test case. Large orders for the case were then placed, and cases taken at random from the factory were examined by an officer from the Royal Army Medical College. The test case then became a general issue to troops, both at home and in the field, and it was in use in very nearly its original form at the end of the war.

Experiences in France with Water Tanks.

In the first week of November 1914, the Army Sanitary Committee visited France and made a careful examination of the water carts in the possession of divisions in the front line. They found, as had been expected, that all the carts depending on filter candles for the sterilization of water had broken down, and the tanks were mainly used for the carriage of water sterilized by chloride of lime. Fortunately, most of the

sources of water at that time available for troops were comparatively clear, and the water, when adequately treated with chloride of lime, was rendered safe and potable.

Early in June 1915 a committee, which had been appointed in France to formulate requirements of water supplies in the event of an advance, reported on the water tanks then in the possession of the troops. They found that the following types were in use :—

Mark II. „ II. A. „ II. B.	Domed water tank without any apparatus or pumps.
Mark II. C.	Domed water tank fitted with small clarifying cylinders and eight filter candles.
Mark II. D.	Similar tank fitted with large clarifying cylinders and pumps, but no candles.
Mark III.	Barrel-shaped tank, two small clarifiers and eight filter candles.
Mark IV. Mark V.	Barrel-shaped tank, large clarifying cylinders and pumps, but no candles.

The majority of the tanks appeared to be of the Mark V type. Unfortunately, the constant jars the tanks received on the bad roads in France caused the attachment of the clarifying cylinder to the tank to become loose, and when the pump was worked the clarifiers were often torn away from the tank. In the 5th Corps, 40 per cent. of the tanks were rendered useless from this cause, and as it was impossible to repair the tanks in the time available, the clarifiers were removed, and the tanks issued as simple water carriers.

The committee did not agree to the removal of the clarifiers ; they thought the general principles of the Mark V tanks were good, but recommended that the clarifiers should not be attached to the body of the cart. They stated : " We consider it desirable that there should be some means of clarification provided on the cart for clarifying small quantities of water in case of emergency, provided that the apparatus can be transported without damage to itself or the tank. We consider that this end can be obtained if one clarifying cylinder and a pump are carried in a box which would be fitted to the cart and closed when not actually in use. It would be necessary also to provide a screw clamp to fix the pump to the framework of the cart when required for work. Flexible armoured suction and delivery pipes should also be provided."

Experience showed that for small isolated units or messes dependent upon any chance supply, the portable clarifier had

an undoubted field of usefulness, whilst for troops on the march, dependent upon any wayside source, the use of the water-cart clarifier was found to be of great value and at times absolutely essential.

A Mark VI cart was then designed in order to meet the defects which had arisen in France. The cylindrical body and vertically placed pumps were retained, but the clarifying cylinders were now placed in front of the cylindrical tank and supported by the body of the cart, flexible hose connected the pump to the clarifier, and similar hose conveyed the clarified water back to the top of the tank.

In July 1918 a Mark VII tank was made, which was similar to Mark VI, but the body was stronger. The transverse draw-off pipe was furnished with a pair of steadying stays and the pipe connecting the tank to the draw-off pipe was of rubber tubing, the ends of which were secured on metal ferrules by steel clips. A stop-cock was provided to the pipe connecting the tank to the draw-off pipe.

The Removal of Poisons from Water.

In view of the reports received in June 1915 that the Germans had poisoned wells in South-west Africa with sodium arsenite, the question of the removal of poisons from water was taken up, and Professor H. B. Baker was consulted. He thought that the poisons most likely to be employed would be salts of lead, copper, mercury, arsenic, and soluble cyanides, and he devised a small portable test case for the detection of these poisons. Issues of this case were at once made to medical officers in charge of troops.

Professor Baker also suggested the following processes for the removal of lead, mercury, arsenic, cyanides, and copper from water:—

Lead.—Lead is removed as sulphide by the addition of alum and sodium sulphide. The alum acts as a coagulant and must be added *first*. The amount of alum required is between 20 and 30 mgm. per litre. The amount of sodium sulphide necessary is calculated after preliminary examination of a sample of the water and a quantity slightly in excess of that amount is added. The minimum time that must be allowed between addition of the reagents and filtration is fifteen minutes.

Mercury.—Mercury is also removed as sulphide by the addition of alum and sodium sulphide. At least fifteen minutes must be allowed to elapse between the addition of the reagents and filtration.

Arsenic.—Arsenic is removed as basic ferric arsenate. If wholly present as arsenate, all that is necessary is the addition of the correct amount of iron alum; 0·3 gm. of sodium arsenate requires 1 grain of alum for complete precipitation, and fifteen minutes contact is required before the arsenic is completely precipitated. If the concentration of arsenate is greater than 4 gm. of Na_2HAsO_4, $7H_2O$ per litre then addition of lime is necessary. If the arsenic

is present as an arsenite it must be oxidized to arsenate by addition of the requisite quantity of bleaching powder before precipitation with iron alum. The bleaching powder is added in slight excess as shown by starch-iodide paper and is allowed to act on the arsenite for at least four minutes before the addition of iron alum. The quantity of iron alum necessary for complete precipitation is not proportional to the amount of arsenate present but falls off with increasing concentration. This is due to the fact that in stronger solutions some of the arsenate is precipitated as calcium arsenate. Since the addition of iron alum tends to make the solution acid, it is necessary, with solutions containing more than 150 mgm. of $As_2 O_5$ per litre, and in all cases advisable to add some free lime with the bleaching powder.

The removal of soluble arsenates from drinking water may also be effected by the addition of ferric chloride and caustic soda solutions. In this process the ferric chloride is added first and then sufficient caustic soda to form a compact precipitate.

The reaction proceeds rapidly and a heavy precipitate is obtained at all dilutions, but with strong solutions of arsenate (i.e., corresponding to 400 mgm. $Ao_2 O_5$ or more), the treated water has a very saline taste due to the comparatively large quantities of ferric chloride and soda required for the removal.

Cyanide.—The removal of cyanide depends on the formation of potassic-ferrous ferrocyanide [K_2 Fe (Fe CN_6)]. It is necessary for the complete removal of cyanide to have a little alkali present since this depresses the amount of free HCN in the solution. Free HCN does not readily act on ferrous salt, but with alkali present reaction goes to completion. The alkali added has to be destroyed by addition of the requisite excess of ferrous sulphate, so that the precipitate obtained contains quantities of ferrous hydroxide in addition to the cyanogen compound. If alkali in excess is added the filtrate will be yellow, due to the presence of ferrocyanide, but as the ferrocyanide is harmless it is preferable to having excess of iron, since in the latter case the liquid gets muddy after filtration through oxidation of the ferrous sulphate to various hydrates of iron. The precipitate itself (left on a sand filter) oxidizes gradually in the air with liberation of potassium ferrocyanide, so that where possible the sand in a filter should be washed before each filtration.

The caustic soda must be added to the alkaline water first and then the ferrous sulphate. After about ten minutes the precipitate will have coagulated and be fit for removal by filtration.

Copper.—Copper is removed as hydroxide by the addition of lime. For every 5 gm. of $CuSO_4$, $5H_2O$, 6 gm. of lime are to be added.

Trials of these processes were made first in enamelled iron pans of about one gallon capacity, and then in a large blocked-up sink, holding 12 gallons. Attempts were next made to remove poisons from water in the ordinary water tank cart; it was found that the cloth filter was not sufficiently close to remove arsenate of iron, and was readily blocked by colloidal prussian blue. The reel was removed from the cylinder and replaced by a bag of sand; better filtration results were then obtained, but the pressure rose rapidly and the pumps were easily strained.

It was evident that on active service water-carts fitted with a sand strainer could not be worked with success, and attention was then directed to the construction of special machines for the removal of poisons from water; it was obvious that to save transport the machines must also be adapted for

clarifying and chlorinating water intended for drinking purposes. It was considered that the machines might be of three types: (*a*) horse-drawn plants, having a delivery of about 100 gallons per hour, suitable for use with mounted troops, and to supply water to infantry in the front line when roads and bridges were not in fit condition for motor traffic; (*b*) plants on motors, delivering a minimum output of 400 gallons per hour; and (*c*) plants on barges, delivering 4,000 gallons per hour. Representatives of the chief firms making a speciality of water purification were interviewed at the War Office, and the following requirements were explained:—

(1) Two tanks for the first and second treatment with the chemicals required for the removal of certain poisons, the first tank to be of such a size that the chemical reaction of the first treatment would be completed before the water arrived in the second chamber.

(2) Means of dosing the chemicals required for treatment at a varying rate according to the amount of poison found in the water.

(3) A filter to remove the precipitates resulting from the chemical treatment; a preliminary roughing filter followed by a sand filter would probably be required.

(4) A pump to give a uniform delivery to the machines. In the horse-drawn plant the pump might probably be worked by hand, but in the larger plants on motors some form of engine would be required.

(5) A small laboratory on the chassis of the motor plants in which the chemists could make their preliminary analysis of the water to be treated and determine the nature and amount of the poison and calculate the dose of chemicals required to remove the poison found.

Such plants could easily be used for the clarification and sterilization of water, but the procedure would be slightly different from that usually employed. Owing to filtration through the sand filter coming last in the treatment of water for the removal of poison, the raw water would have to be chlorinated in the first tank by means of the dosing apparatus, the size of the tank allowing a considerable time for contact; the alum treatment would take place in the second tank and filtration through the sand filter to remove coagulated suspended matter would then follow. The amount of chloride of lime required for the raw water would be determined by means of the water sterilization test case, already described. The United Water Softeners Company submitted designs for a horse-drawn plant, and for a plant on a motor, which seemed to fulfil the requirements for the removal of poisons from water, and for use as a sterilizer. The same company also had designed a very useful plant for the sterilization of water by means of chloride of lime, and subsequent dechlorination by the action of ferrous sulphate and sodium sulphite followed by filtration through permutit. This plant had been tested at the Royal

Army Medical College before the outbreak of war. It could be coupled up to the depoisoning plant and used to sterilize the water after the poison had been removed. Messrs. Ransome and Ver Mehr, Bell Brothers and the United Water Softeners Company prepared designs for the installation in a barge of plant designed to remove poisons from water, and deliver per hour 4,000 gallons of water sterilized by means of chloride of lime.

The horse-drawn plant delivering 125 gallons an hour was ordered first, and a complete series of tests on the removal of poisons from water in movement was made at the Montgomery Wharf, Brentford, then occupied by the United Water Softeners Company. The results were satisfactory on the whole, but the labour of pumping water hour after hour was very great and wasteful in man-power. Two small engines were then fitted and the apparatus was worked with great success. The cost of such an apparatus, considering the small delivery, would, however, have been very great, and it was considered wiser to concentrate on a plant, placed on a motor lorry, which could easily deliver 400 gallons per hour, and to send forward the purified water by means of tanks placed on 1-ton, or 1½-ton motors.

The results of the preliminary work were communicated to General Headquarters in France, who were informed that it seemed possible to construct plant for the sterilization of water and for the removal of poisons from water, suitable for installation on barges or on motors.

The War Office was then requested to obtain and test the motor plants designed for the sterilization of water and for the removal of poisons from water, and to place orders for five barges, as soon as the best type had been selected. After consultation with the Quartermaster-General's department, the United Water Softeners Company was requested to send to Brentford for trial a motor plant for the sterilization of water, and a motor plant for the removal of poisons from water. The general design and method of working of these plants will be readily understood from the following brief descriptions.

Mobile Plant for the Sterilization of Water.

This plant is designed to filter and sterilize water by a continuous process at the rate of 400 gallons per hour, the sterilizing chemical being bleaching powder (chloride of lime). (Fig. 1.)

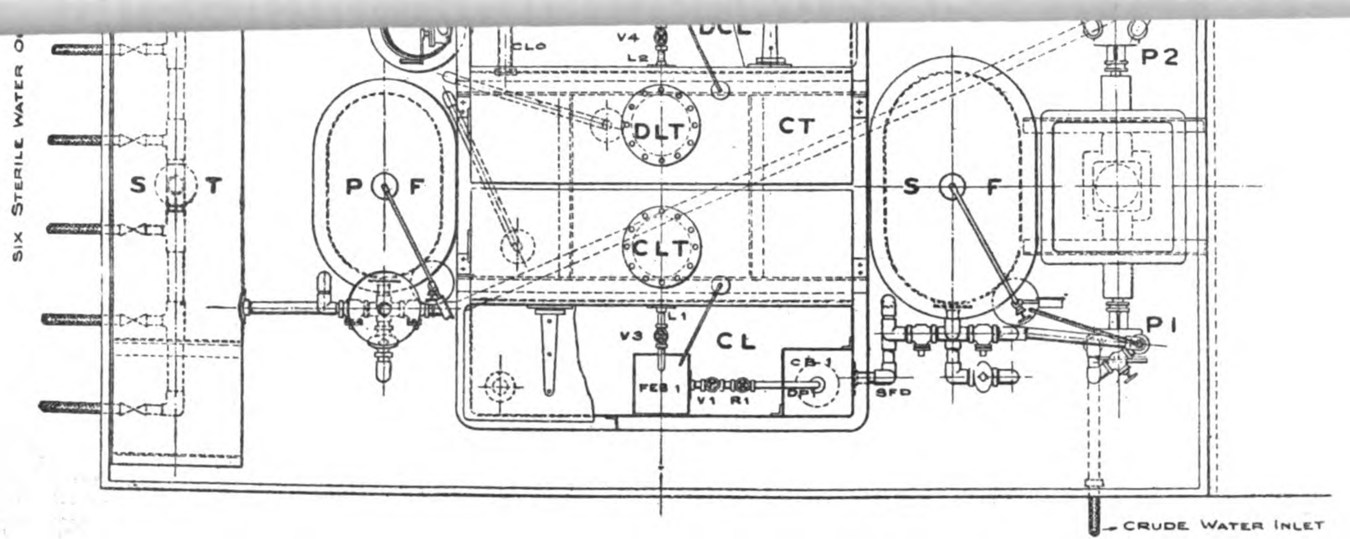

FIG. I. CHLOR-"PERMUTIT" WATER STERILISER.

UNITED WATER SOFTENERS LIMITED.

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The excess of chlorine in the bleaching powder after sterilization is completed, is removed by means of a mixture of sodium bisulphite and ferrous sulphate, the excess of ferrous sulphate being in turn removed by means of manganese permutit.

The plant consisted of four main portions :—

(*a*) Pumping unit.
(*b*) Mechanical sand filter (pressure type).
(*c*) Treatment and contact tank.
(*d*) Permutit filter (afterwards changed into a second sand filter).

The pumping unit consists of two 1-in. rotoplunge pumps directly coupled to a 1½-h.p. Lister petrol engine. The speed of the engine remains constant at 450 revolutions per minute and the rate of flow of the water from the pumps is regulated by a by-pass arrangement fitted to each pump.

One of the pumps (P1) pumps the water from the source and through the sand filter. This filter is partly filled with graded gravel to form a bed on which rests the filtering sand. The filter is fitted with a standard arrangement of five valves (SF1, 2, 3, 4 and 5) by which the flow of the water through the filter can be directed either from top to bottom (filtration) or from bottom to top (back-flushing).

On starting the plant the crude water is sent into the filter from the bottom and allowed to pass out of the top and go to waste, this being done to clean or backflush the sand and, at the same time, to remove all air from the sand and thus form a solid filtering bed. For this purpose valves SF4 and SF2 are opened and SF1, SF3 and SF5 shut.

As soon as the water passing from the filter is clear, its direction is changed by opening valve SF1 and shutting SF4, opening SF5 and closing SF2. Water now flows away from the plant through valve SF5, and in this way any unfiltered or partly filtered water is prevented from entering the treatment tank.

After a short time valve SF3 is opened and SF5 shut. Filtration now proceeds, water passing from the top downwards through the sand, any air carried with the water from the pump being released by the small air release line valve AV1, which is set to allow a trickle of water to escape continuously. If necessary, a solution of alum or aluminium sulphate can be sucked into the filter in order to form a filtering medium on the surface of the sand and thus render filtration more easy.

After the water has been filtered it passes to the treatment tank, which it enters by way of the catch box CB1, and into which is also fed, from the air-tight tank CLT, a solution of bleaching powder at such a rate that the quantity of chlorine, as indicated by tests with the water sterilizing test case, is constantly maintained in the water. The rate of addition of the bleaching powder is rendered constant by keeping the small feed box FEB1 filled with the solution to a constant level. This is carried out by means of the " chicken feed " arrangement. The tank CLT containing the solution of bleaching powder is air-tight except for a small pipe which leads from the top of it and just dips into the feed box. On filling this box by opening the valve V3, bleaching powder solution runs from the tank CLT until the open end of the small pipe leading from this tank is just covered. No air can now enter the tank CLT, and consequently no more bleaching powder solution can flow from it. As bleaching powder is admitted to the water by means of the valve R1, valve V1 only being used to shut off the supply and at the same time not interfere with the setting of the valve R1, the level in the feed box FEB1 is lowered ; the end of the small pipe is then uncovered, and thus air is admitted to tank CLT, allowing more bleaching powder solution to flow into the feed box FEB1 and maintain the level. By this arrangement a steady flow of bleaching powder solution is added to the water entering the

catch box CB1, the quantity being regulated until the desired amount of chlorine is added to the water. This is tested by a simple colorimetric test, by comparing the blue colour produced by adding a little potassium iodide and starch solution to a standard quantity of the water and comparing with standard colours.

The water and the bleaching powder solution mix together in the catch box and pass to the bottom of the first compartment CL of the contact tank, and then, when this is filled, the water passes over the weir into the second compartment CT, which is divided into two portions by means of a baffle which reaches nearly to the bottom. From this compartment the flow is directed upwards into the second portion, and when this is filled the now sterilized water passes through a pipe into the catch box CB2. Into this box is fed the requisite amount of a solution of the dechlorinating chemical from the air-tight tank DLT by a similar arrangement to that previously described for the delivery of the bleaching powder. For this purpose a mixture of sodium bisulphite and ferrous sulphate is added. The quantities of these chemicals are so arranged that while the whole of the sodium bisulphite is oxidized by the chlorine, the amount of ferrous sulphate is just in excess of that which will be oxidized by the chlorine not required to oxidize the sodium bisulphite. The iron salts are then removed by passing through a bed of manganese permutit. This substance has the property of converting iron salts in solution to insoluble ferric oxide, which is filtered out by the bed of the permutit. After some time the permutit is unable to bring this chemical change about, and it is necessary to regenerate it by treatment with a solution of potassium permanganate. The water after sterilization and dechlorination now passes through the apparatus containing the permutit. The water is pumped from the dechlorinating tank to this filter by means of the pump P2, the rate being regulated by means of the by-pass on the pump. From here it passes to the storage tanks or to water-carts.

From time to time colorimetric tests are carried out to see that the chlorine which is being added is in accordance with the results of the tests with the water sterilization test case. Any adjustment that may be necessary is made by means of the valves R1 and R2.

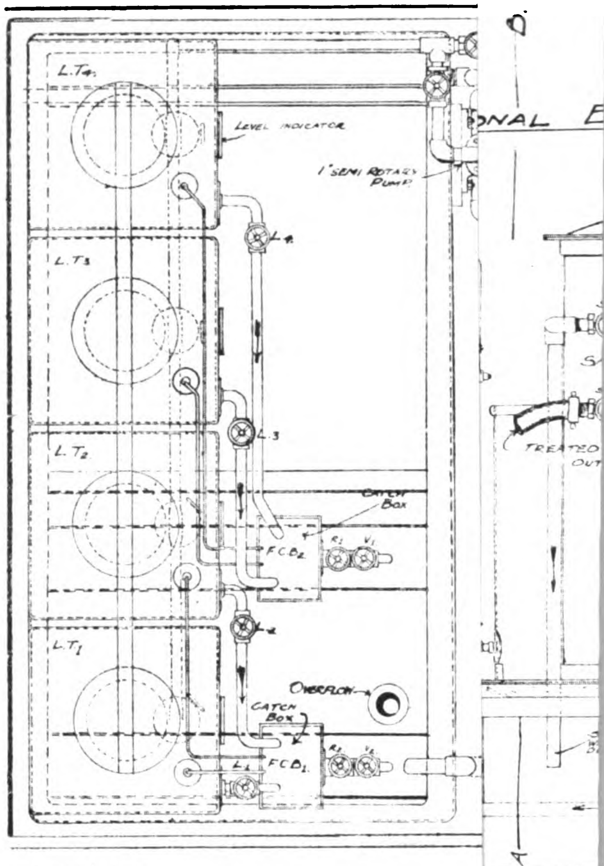
Mobile Plant for Removal of Poisons.

This plant was designed for the purpose of purifying water which might have been accidentally or purposely contaminated by cyanides, arsenic compounds and such metallic salts as copper sulphate or lead acetate By it the water is purified and rendered quite free from poison at the rate of 400 gallons per hour, but no special attempt is made to sterilize the water at the same time. If sterilization is necessary the water is treated later by a mobile motor sterilizer, as noted below. (Fig. 2).

Before the machine can be used it is necessary for a chemist to detect and estimate the poison present in the water. When this is known the exact method that is to be adopted is decided upon and the various chemical solutions required for the process are made up to the necessary strengths.

The principle of this process is to convert the soluble poison into an insoluble substance by the addition of the requisite chemicals and to filter this insoluble substance from the water.

PLA



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It was recognized that these machines would probably have a very restricted use for eliminating poisons, and they were therefore constructed so that they could be used to sterilize water if they were not required to remove poisons.

Fig. 2.—Plant for depoisoning and plant for sterilizing water working together.

The plant (Fig. 3) consisted of the following parts :—

(*a*) Pumping unit.
(*b*) Treatment tanks.
(*c*) Solution tanks and mixers for chemical solutions.
(*d*) Sand filter.

The pumping unit consists of two 1-in. rotoplunge pumps directly coupled to a $1\frac{1}{4}$-h.p. Lister engine. The speed of this engine remains constant at 450 revolutions per minute, and the rate of the water pumped is regulated by means of by-passes fitted to each pump.

One of the pumps, P1, pumps the water from the source to the mixing trough at the top of the first compartment of the treatment tank. Here it is treated with the correct amount of the first chemical that is used, which is supplied from the two chemical storage tanks LT_1 and LT_2. The flow of this chemical is regulated by means of a valve fitted to the standard type of "chicken feed." For carrying out the process only two chemicals are ever required and solutions of these chemicals are kept in the tanks LT_1, LT_2, LT_3 and LT_4, the tanks being arranged in pairs so that the process need not be interrupted owing to the supply of chemical being used up. The solutions are made up in the chemical dissolvers A, and are pumped to the storage tanks by means of a hand pump.

After the water has been treated with the first chemical in the trough, it flows over the top into the first compartment of the first treatment tank. It flows under the baffle partition and, when the second compartment is full, it flows into the second treatment trough through perforations at the back of it. Here it is treated with the second or precipitating chemical and then flows to the bottom of the large compartment of the second tank. In passing upwards it meets a tightly packed bed of wood-wool and a large portion of the precipitated chemical is filtered out. The partly filtered and depoisoned water then flows into the last and smallest compartment of the tank and is then pumped to the sand filter by pump P2. This is fitted with the standard arrangement of valves and is used in exactly the same way as that described under the "mobile motor sterilizer." Filtration is completed, and if the process has been carried out carefully and controlled by chemical tests it will be found that the whole of the poison has been removed.

Practically all tests can be carried out colorimetrically, and it is only necessary to prepare a standard set of colours by chemical experiment to determine the amount of poison present.

Arsenic is removed by first oxidizing the salt present to the arsenic state by means of a solution of bleaching powder added from the first of the reagent tanks, and it is then converted to a basic ferric arsenate by the addition of a solution of iron alum from the third reagent tank.

The yellow basic ferric arsenate is easily filtered from the water. Arsenic as arsenite is detected colorimetrically by adding a solution of sodium sulphide and dilute sulphuric acid. A yellow colour is given by less than 1 mgm. as As_2O_3 per litre. Arsenic as arsenite or arsenate is detected and estimated by means of Marsh's test.

Cyanide is removed by the addition of a solution of sodium hydrate from the first of the reagent tanks and by the addition of ferrous sulphate solution from the third. A blue precipitate is formed which contains the whole of the cyanide and is easily filtered off.

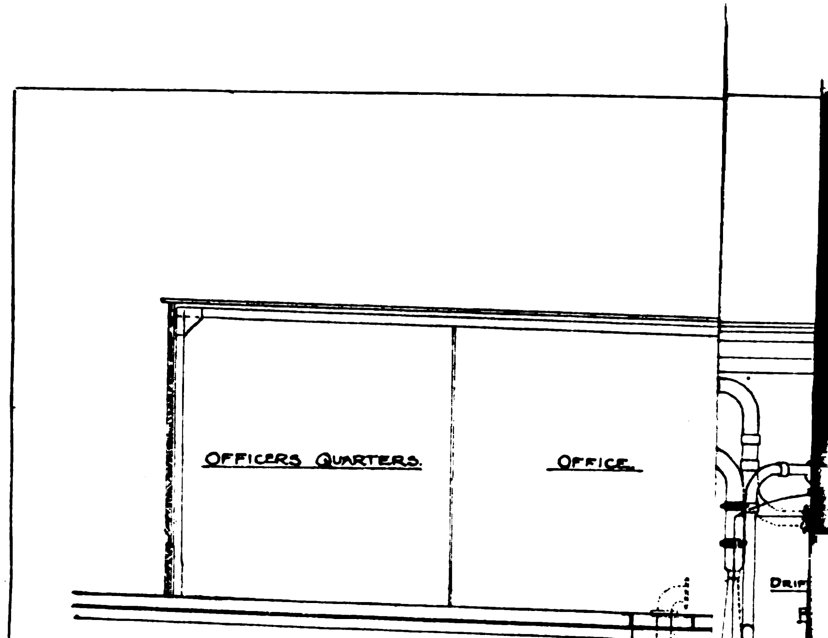
Cyanide is detected by adding a dilute solution of silver nitrate to the water made alkaline with sodium hydrate. Salts of lead, copper, mercury and other heavy metals are removed by adding alum or aluminium sulphate solution from the first tanks and a solution of sodium sulphide from the others. The alum is added first to produce "flocking" of the insoluble sulphide produced by the action of the sodium sulphide on the salt of the metal present. The heavy metals are detected by means of a solution of sodium sulphide, the estimation being carried out colorimetrically.

In all this work the detection can be converted into an estimation by working with standard quantities of water and standard solutions of the metallic salts that are present.

In working these depoisoners a good deal of accurate chemical work had to be done and a small laboratory was fitted up on the machine so that all the work entailed could be carried out on the spot.

If it was necessary to sterilize the water after the depoisoning process had been completed a sterilizer was connected to the depoisoner and the two machines run in series.

If it was required to sterilize and not to depoison water, then from the first and second solution tanks alum solution was added and from the third and fourth the requisite quantity of bleaching powder as indicated by the water sterilization test case. Filtration took place after sterilization and no



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attempt was made to dechlorinate. It was necessary to limit the amount of bleaching powder solution to the minimum required to produce sterilization in order to prevent an excessive amount of chlorine in the sterilized water.

Water Purification Barges.

The orders for the barges were placed by the Inland Water Transport Division of the War Office and Captain A. S. Collard, R.E., supplied the necessary barges and gave valuable assistance in obtaining the best arrangements for the purifying plant on board the vessels. The types of plant designed by Messrs. Ransome & Ver Mehr, Bell Bros. and the United Water Softeners Company were somewhat different in the method of dosing with chemicals, and filtering off the precipitates, and the following is a brief description of the three types.

(1) *Ransome-Ver Mehr Plant.*—This plant was devised to treat 6,000 gallons of poisoned water per hour. The general arrangement of the plant is shown in Fig. 4.

Below the deck aft there is a large store, in front of which are placed the engines. Above the store and engines are the officers' quarters, office, laboratory, water-closet and shower-bath. Then come the two sedimentation tanks, which occupy practically all the space between the upper and lower decks. The tanks are worked in series, the pumps delivering the raw water through a hose pipe over the side of the boat into the bottom of the first tank; at the point of delivery of the water from the pumps alum, soda or any other chemical required can be injected by means of air pressure cylinders. The raw water passes upwards through the first tank out at the top and is delivered by a pipe to the bottom of the second chamber, through which the partially settled water again rises to the top, from whence it passes to four of the Ransome drifting sand filters. In this type of filter, unlike the Bell, Mather and Platt, and the Water Softeners filters, the upper portion of the filter bed is in a slowly moving condition, the sand being continually withdrawn, washed and replaced automatically by the inflowing water while the filter is at work. This continuous washing process enables the filter to run longer between ordinary washings than the usual type of filter with a stationary sand bed. When washing out of the filter does become necessary, owing to the rise of pressure caused by the accumulation of suspended matter in the sand, it is accomplished by reversal of the flow, a comparatively high velocity being used as compared with the filtering rate.

Between the sedimentation tanks and the filters is the Ransome pressure solution apparatus of which two are provided so that one can be charged while the other is in action. By means of this apparatus alum or soda can be injected into the pressure mains. In front of the filters is placed the large chlorination tank, which is of such a size that the chlorine required, which as chloride of lime solution is injected into the pressure main as it enters the tank, can act on the water for thirty minutes. After leaving the chlorination tank the water passes to distributing mains, which are placed on each side of the deck. Forward of the chlorination tank there is again a deck on which is placed the chemical solution plant, consisting of a water storage tank, mixing tank below this and the necessary fittings. In the tanks chloride of lime solution can be made up, the amount required having been previously determined by analysis in the laboratory, and also sulphite of soda for dechlorination of the sterilized water when this is found to be necessary.

Solutions for the removal of poisons from water are also prepared in these tanks. Below the chemical solution tanks is placed the Ransome compressed air apparatus by means of which the chemical solutions prepared in the tanks on the deck above are injected into the main by air pressure obtained from a small compressor. Solutions can be injected at the entry of the water to each of the sedimentation tanks, before the filters and before and after the chlorination tank. Pipe-lines are taken from the outlet of the sedimentation tanks, from the filter effluent and from the exit of the chlorination tank to taps in the laboratory; in this way the working of each part of the plant can be effectively controlled. In the bow of the boat are placed the men's quarters.

Much was expected from the Ransome filter, the work of which is illustrated in Fig. 5. The diagram shows the location and form of the upper layers of filtering material, composed of the drifting sand. These upper layers are supported by the stationary sand B. The filtered water collecting system C (which also forms the distributor for the incoming water when washing out) is placed at the bottom of the stationary sand, and consists of a grid of pipes into which gunmetal strainers are screwed. The drifting sand travels down the extractors D, situated around the circumference of the filter, through the pipes E to the sandwasher F. Here the sand is agitated by the water entering the washer at G, through the pipe Z, the dirt is removed and a small flow of dirty water continually passes away at H. The clean sand gravitates to the bottom of the washer and finds its way into the throat J in the inlet pipe K; the velocity at this point carries the sand upwards with the unfiltered water and deposits it on the top of the drifting sand A. When filtering, the water enters through the pipe K, passes through the sand A, which removes the bulk of the suspended matter; the stationary sand B completes the clarification and the water passes away through C and the pipe L. The continuous washing process as above described does not wholly remove the dirt in the sand A, neither does it have any effect on the dirt arrested in the sand B; therefore, a time arrives when the accumulated matter renders ordinary washing out necessary. This is accomplished by reversal of the flow; the water enters at L, passes upward through C and the sand B and A, loosening it and carrying away the dirt through the pipe M. The drifting and washing of the sand during the working of the filter is effected by utilizing a familiar hydraulic principle known as the Venturi law. In effect, the principle is that if a pipe, through which water is flowing, has a constriction or throat, as shown at J, the extra velocity of the water at this point causes a diminished pressure, the amount depending upon the size of the throat and the rate of flow of the water; the pressure is, however, regained when

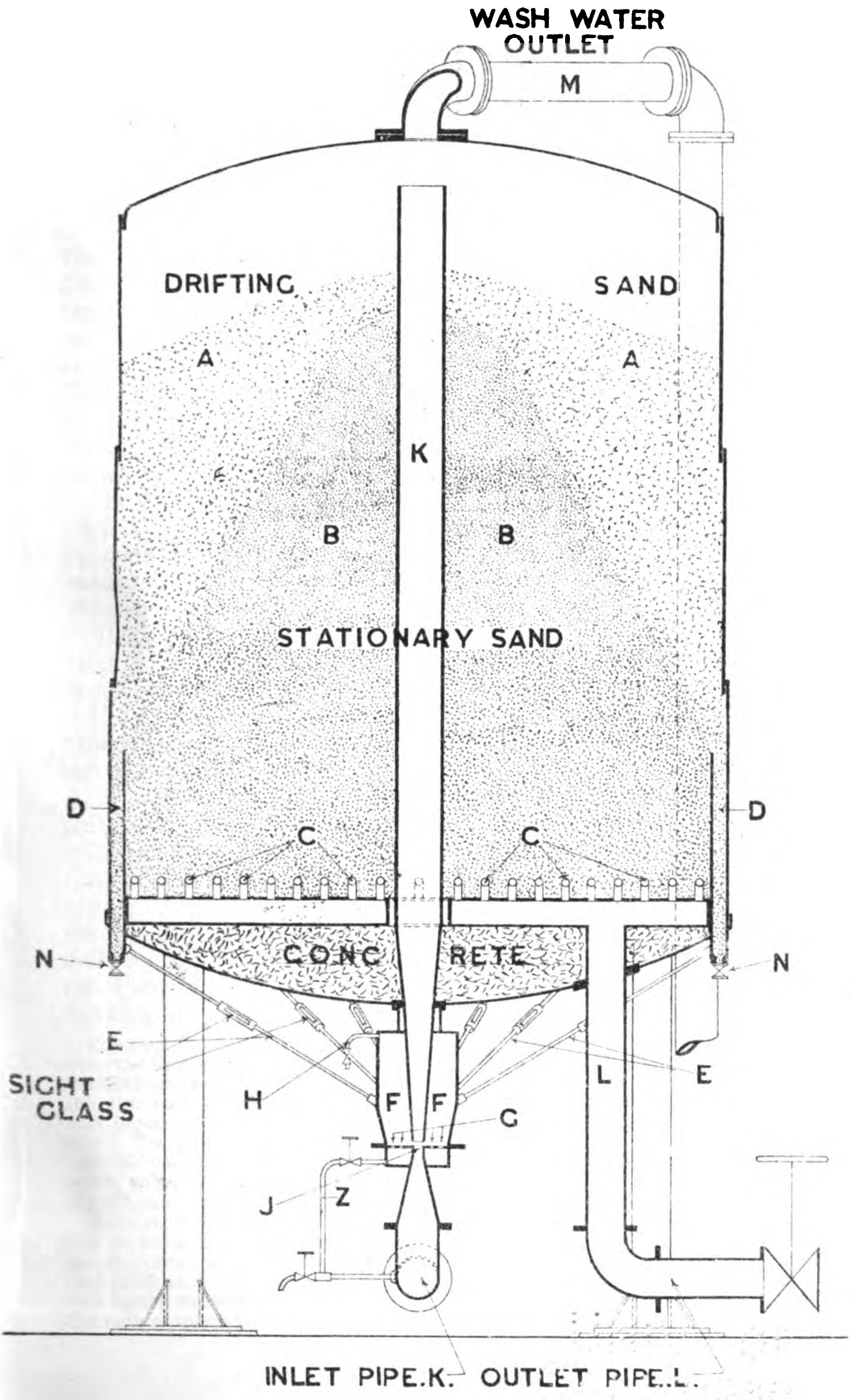

FIG. 5.—RANSOME VER MEHR FILTER.

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the full size of the pipe is again reached. For instance, if with a given flow there is a pressure of 50 lb. to the square inch on the inlet side of J, it is possible to have a pressure of 45 lb. at the throat and practically 50 lb. again on the outlet side. The lesser pressure at the throat J in the sand-washer of the filter means that the pressure in the washer itself is that of the throat, because the washer is a chamber round the throat and in communication with it. On the other hand, the water in the filter on top of the sand is at the full inlet pipe pressure. The result is that this superior pressure tends to push the sand down the extractors into the washer and ultimately into the throat J, and the moving sand in the filter takes the form shown in the diagram.

The difference in pressure between the water flowing in the pipe K and that in the washer F causes the water to flow through Z, enter the washer by a spreading arrangement surrounding J and agitate the sand falling into the washer through the pipes E.

The pipe Z is not fitted to all filters of this type; in the later models it has been dispensed with, as the water coming down E with the sand was found to wash it sufficiently.

If by accident or any other cause the drifting sand principle cannot be used, the filter then becomes similar to an ordinary mechanical filter, and can be worked as such.

(2) *Bell's Plant.*—This plant was designed to treat 4,000 gallons of poisoned water per hour, and consists of tanks and cylinders for making and adding chemical solutions in regulated quantities; an oil engine and pump for obtaining the water supply from the river or canal; sedimentation tanks; filtration plant; contact chamber for chlorination, and a system of delivery pipes and valves for discharging the water. The functions of each part of the apparatus and the method of working are as follows (Fig. 6):—

Pumping Plant.—This consists of a 5½-b.h.p. oil engine, which draws water from the source of supply and passes it forward in a continuous flow through the contact chambers, filters and chlorinating chamber, and finally through the distributing mains placed on deck to various valve controlled outlets; hose piping is provided so that the water can be discharged alongside or on shore. The pump is, as a matter of fact, the motive power which practically puts the whole plant into operation. The pump is double geared or, in other words, so arranged that it runs at two speeds, the slower of which is used during the filtration operation, and the higher speed at times of cleansing the filters.

Sedimentation Tanks.—These are in duplicate and so arranged that they can be worked in parallel or in sequence, and are of ample size to give time for the chemicals introduced to act fully. In addition to being contact chambers, they also operate as sedimentation chambers, and with waters undergoing treatment containing a considerable amount of suspended matter, the bulk of this is removed by sedimentation before the water passes forward

to the filtration plant. Special inlets and outlets are provided to ensure an even flow through the chambers and to prevent currents through any one part. The heavy solids settle against the upward current and accumulate in the base, and when necessary can be blown out.

Filtration Plant.—Three Bell's patent filters, 4 ft. in diameter, receive the water from the settling or contact chambers, and each filter treats one third of the total quantity passing forward, removing from the water all matters in suspension and a high percentage of bacteria.

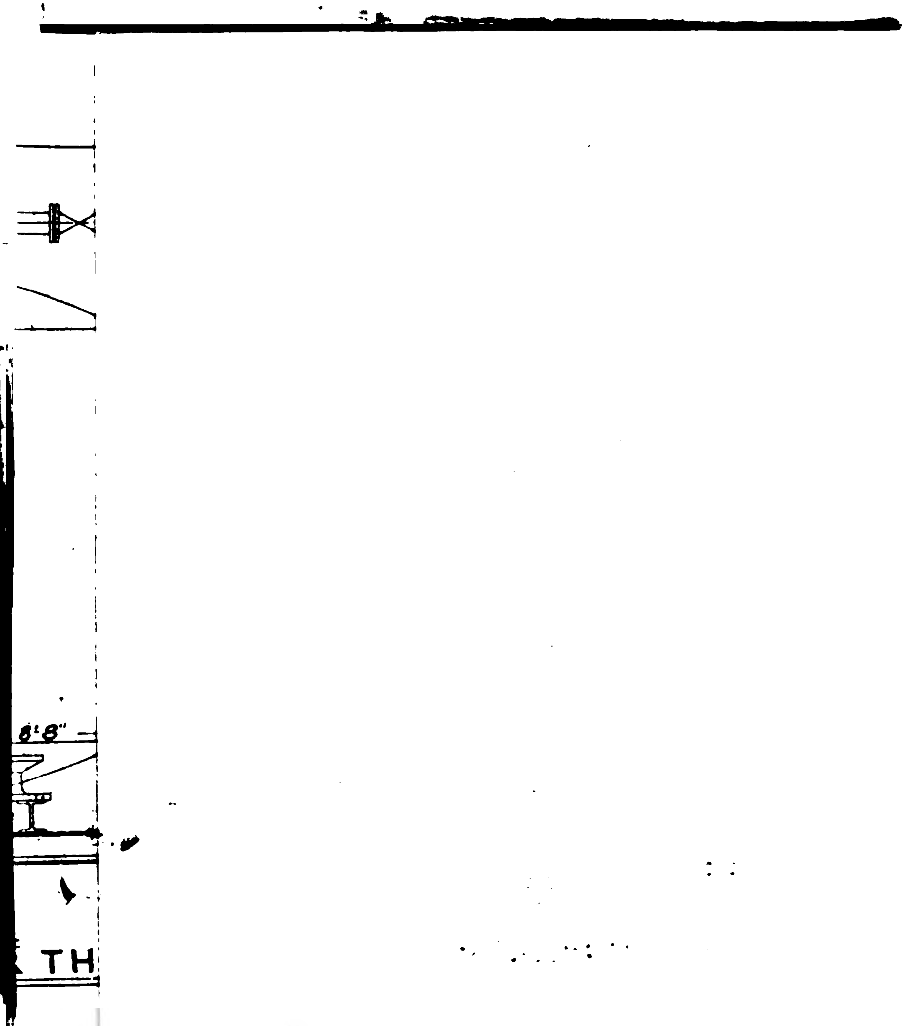
Chlorinating Chamber.—As a further line of defence a suitable contact chlorinating chamber is used through which the chemically treated, settled and filtered water passes, and on entering at the base of the chamber is treated by chloride of lime solution, and thus time is given for a thorough mixing and action of the solution before the water is discharged at the top of the barge.

Chemical Treatment Tanks.—This apparatus is of an elaborate nature, due to the many functions that the plant might be called upon to perform. For the treatment of the water before it enters into the two sedimentation tanks a series of open tanks is provided in which weighed quantities of chemicals and measured quantities of water are placed so as to make standard solutions. The water used in these tanks is the filtered and purified water stored in bulk in a water supply tank fixed above the chemical tanks. The chemicals are introduced into the water on the suction side of the main pump by means of a small pump driven by the main pump and working at the same rate. Between the sedimentation tanks and the filters further provision is made for adding alumina and lime, the two chemicals chiefly used for treating ordinary water supplies for the removal of bacteria, vegetable discoloration and clay. The introduction of these two chemicals into the water about to pass from the sedimentation tanks to the filtration plant is effected by means of Bell's patent Venturi control. The third place of chemical treatment is between the filters and the chlorination chamber, and to hold the standard chloride of lime solution duplicate closed pressure tanks are provided, either of which can be charged or filled with standard solution from a mixing tank situated above, the solution being injected into the water supply by means of compressed air.

A well-equipped laboratory is provided on board, in which all the required chemical and bacteriological examinations can be made. There are also quarters for two chemist officers and for the crew.

(3) *United Water Softeners Company Plant.*—This plant, designed to treat 4,000 gallons of poisoned water per hour, consists of pumping units driven by petrol engines, sedimentation tanks, automatic chemical treatment apparatus, sand filters, sterilizing tanks, a manganese permutit filter, sterile water storage tank, and pure water service mains, together with a fully equipped laboratory, electric light, stores, and quarters for officers and men.

Crude water is picked up by the first pump from the selected source and delivered into the sedimentation tank, where it receives automatically an accurately dosed chemical treatment in proportion to the rate of flow. This tank, divided into two portions, each fitted with baffles and weirs, allows in the first part a thorough mixing and contact between the water and chemicals ; and the second portion, acting as a settling tank, is provided with a wood-wool filter, through which the water passes slowly in an upward direction. The first portion of the tank is amply baffled in order to cause the chemically treated water to take a very circuitous route before passing over the weir into the second compartment, where the precipitated matter settles out or is held up by the wood-wool.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From this tank the water is pumped direct to two pressure sand filters working in parallel. These filters render the water entirely free from any suspended matter and sparklingly clear. As they become after a time more or less heavily charged with accumulated matter, they require back-flushing to cleanse them, and for this purpose piping and valves provide for reversal of flow, the pure water stored in the sterile tank being used for this purpose.

After filtration the water may be delivered either into the contact tank to be sterilized or direct to service.

The contact tank is also provided with a series of baffles and weirs, besides automatic chemical dosing equipment. The water entering is treated with the predetermined amount of reagent from tanks, after which a period of contact of about thirty minutes is allowed before further treatment with the required reagent to remove all trace of the sterilizing agent.

After sterilization the water is picked up by the second pump and forwarded through the manganese permutit filter for final removal of any traces of iron held in solution or slight suspension. This filter is arranged upon similar lines to the sand filters, and when necessary can be back-flushed by pumping the water in a reverse direction to that during filtration, the dirty water in this case, as in the sand filters, being discharged overboard. Provision is made for regenerating the permutit by means of a mixing tank and pump.

From the permutit filter the water is finally passed to a ring main which circles the entire barge, with tappings at convenient points. By means of this ring main the sterile tank or any outside storage, may be supplied; or the pure water may be delivered by means of flexible pipe connections to any point at a distance.

The installation is provided with sampling draw-offs at all stages, so that quantitive determinations may be made after the first chemical application, after filtration and after sterilization. Thus the officers in charge have full control and are afforded easy means of adjusting the whole plant.

Provision is made by which the crude water pump can be employed to pump out the bilge, either fore or aft, and the electric generator which drives the intermediate pumping set can be run to charge storage batteries in the fore peak, when not required for operating the purification plant.

Practical Tests with "Depoisoning" and Sterilizing Plants.

A long series of tests was carried out at Brentford with the "depoisoning" plant. A large tank was filled from the local water supply and the various poisons were added, with increasing doses up to 100 mgm. per litre; the poisoned water was then pumped continuously through the machine for several hours. Even with the heaviest dosage no difficulty was experienced in bringing the amount of poison well within the non-poisonous dose, and usually the poison was completely removed. Tests with the water-sterilizing plant were made with the natural water in a creek adjacent to the wharf; this water was heavily polluted and often contained *B. coli* in $\frac{1}{1000}$ c.c. The effluent from the plant did not contain *B. coli* in 100 cc., and suspended matter was completely removed.

The tests on the barges for the removal of poisons were carried out in the docks at Poplar, where the fitting up of the barges was carried out by Captain A. C. Jervis, R.E., and where there was every facility for structural changes, should

these be found necessary. The delivery of each barge was 4,000 gallons per hour, so that it was necessary to poison a large volume of water for a run of several hours. Store barges containing tanks were brought alongside the barge to be tested; the tanks were filled with fresh water from a stand-pipe on the dock side, and a definite dose of the poison was then added and thoroughly mixed with the water in the tanks. The engines in the barges were then started and the poisoned water pumped through the treatment tanks. When the dosage of poison was considerable, it was found that in the case of the Bell and Water Softeners types the normal delivery of 4,000 gallons per hour could not be kept up; but when the delivery was reduced to 3,000 gallons per hour, very good results were obtained. In similar circumstances the Ransome–Ver Mehr type, which was calculated to give 6,000 gallons per hour, could only be relied upon to deliver 4,000 gallons per hour. As the water in the docks was saline, the barges were brought up to Richmond, and clarification and sterilization tests were made on the Thames water. During these tests the condition of the water varied from day to day, sometimes almost from hour to hour. Sometimes the water was heavily loaded with suspended matter, and there was a strong current. At other times, the current would be slack and the water would then be comparatively clear. Even with these constantly changing conditions the barges invariably produced a clear and practically sterile effluent. When the dosage of free chlorine was properly adjusted, *B. coli* was never found in 100 c.c. of the effluent water from the delivery hose. The constant variation in the physical, chemical and bacteriological conditions of the water required great vigilance on the part of the chemists and frequent tests as to the amount of chlorine required, if the best results were to be obtained.

As a result of this experimental work it was evident that plants could be obtained suitable for motors and barges, which could be relied upon to remove poisons from water, where necessary, and to supply a good drinking water from canals, rivers or lakes. Orders were then placed by the War Office with the Ransome–Ver Mehr Company for two additional barge plants, and with Messrs. Bell Bros. for one more plant, making a total of six plants. Two of the barges left for France in December 1915, each accompanied by a store barge for the carriage of chemicals, and by four other barges containing tanks with a water storage capacity of 12,000 gallons each, and equipped with necessary hose and a pump to enable the

treated water to be delivered at any required point on the banks of a river or canal. The chemists in charge of the barges had been provided with detailed instructions on water purification.*

Water Supply for an Advance.

In May 1915, the General Staff in France had raised the question of the supply of water to the troops in the case of an advance through Flanders. The Committee appointed to deal with the question† furnished a preliminary report dealing with water-carts on 2nd June, as already noted.

On 15th June, Colonel Liddell submitted a full report, together with a summary and a covering letter, to the Q.M.G. of the British Expeditionary Force. In forwarding the report to the War Office, the Commander-in-Chief stated that he did not anticipate that the whole area through which British troops might march was likely to require the special treatment advocated, and considered that it would be sufficient in the first instance to provide water sterilization plants for one corps of three divisions only. The system of supply recommended by the committee necessitated the provision of barges fitted with complete purifying plant, water tank barges for the conveyance of purified water, motor lorries fitted with purifying plant and motor lorries fitted with tanks for the carriage of purified water. The Commander-in-Chief consequently forwarded tables showing the lorries, motor cars, and other equipment required, and a proposed war establishment for a water column for the corps. The report of the committee detailed very fully the importance of these preparations for water purification, as may be gathered from the extract in Appendix C.

Sir John French's letter and the report of the Water Committee were referred to a special War Office Committee, which Lieut.-Colonel W. W. O. Beveridge, the A.D.M.S., Sanitation, came over from France to attend. The supply of water purification barges presented no difficulty, as six were already on order, and would be ready for despatch to France in a short time. As regards the motor water column, the committee considered that the purification plants should, as far as possible, be on a uniform plan, so that the details of working and supply of spare parts might be simplified. The plants already tested

* See Appendix B, 4.

† The Committee was composed of Colonel Liddell, R.E., Lieut.-Colonel Beveridge, A.D.M.S., Sanitation, and Major Wace, of the General Staff.

at Brentford were considered suitable for the sterilization of water and for the removal of poisons, and it was recommended that the numbers specified by Sir John French should be ordered. As regards the carrying tanks, it was impossible at the time to obtain motors carrying 100-gallon tanks, and Ford cars provided with tanks holding 80 gallons of water were suggested in lieu. Experimental trials with the Ford cars in France showed, however, that the cars were not strong enough to carry 80 gallons of water on the bad roads. Garford 1-ton lorries, each carrying a tank holding 150 gallons of water, were then suggested, and on approval of G.H.Q. being obtained, the necessary orders for the supply were placed. A special pump, to enable the water in the tanks to be rapidly transferred to water-carts, was sanctioned for each lorry. The provision of 3-ton motor plants, each carrying 600 gallons of water, and a clarification apparatus for the supply of divisions when resting, presented considerable difficulty; it was found impossible to carry 600 gallons of water and the clarifier on a 3-ton motor, and although the best design obtainable was constructed, it proved too heavy. It was consequently decided that tanks holding 500 gallons of water should be placed on a 3-ton motor, as when divisions were concentrated or resting, there would be ample time to fill the 500 gallons with properly clarified water. Orders were then given for the supply of the necessary motors and tanks. Motor pumps were subsequently fitted so as to enable the tanks to be filled and emptied as rapidly as possible. A special 30-cwt. lorry for the carriage of chemicals required for the "depoisoning" machines was also supplied. Finally, a War Establishment for a Water Tank (M.T.) Company, A.S.C., was approved.

The water tank companies for clarification and sterilizing and depoisoning plant consisted of 186 vehicles, of which one was a 30-cwt. lorry for chemicals; 111 were 150-gallon water tank lorries of which 22 were spare; 19 were clarifying and sterilizing plant 3-ton lorries, 4 of which were spare; and 11 were clarifying and poison-eliminating plant lorries of which 2 were spare. In addition there were 20 3-ton lorries, each carrying a 500-gallon water tank, 4 being spare, and 4 other 3-ton lorries for the carriage of stores.

The companies were Army Service Corps Companies manned by officers and personnel of the Army Service Corps, and each company consisted of a headquarters and three sections. Attached to the headquarters section were one R.A.M.C. officer, who was a chemist with the rank of captain or subaltern,

7 staff-sergeants and sergeants, and 5 rank and file who were employed in connection with the spare clarifying, sterilizing and poison-eliminating plants, and were in charge of the spare 3-ton water tank lorries. In addition to these attached R.A.M.C. there were with each section a captain or subaltern of the R.A.M.C. as chemist, 8 sergeants and 5 privates of the R.A.M.C. for similar duties with the plants of the 500-gallon water tanks.

A Royal Army Medical Corps Water Depôt was next formed at the Montgomery Wharf, Brentford. Arrangements were made with the United Water Softeners Company for the use of a room as an office for storage and for the carrying on of chemical and bacteriological work in their laboratory and of engineering work in their workshops. Mr. R. W. Stickings was commissioned as lieutenant on the general list and placed in charge of the depôt until he went to France. As chemists of No. 1 Water Company, Mr. W. E. Smith and Mr. Cameron were also commissioned and attached to the Water depôt. These officers were subsequently transferred to the R.A.M.C. Specially selected men from the R.A.M.C. depôt were sent to Brentford for training with the new water plants. All these men had some knowledge of chemistry and several possessed university degrees. The officers and men were billeted in Brentford, and arrangements were made for them to attend a short course of instruction in water bacteriology and hygiene, so far as it applied to their work, at the Royal Army Medical College, London.

All machines ordered for the elimination of poisons and for the sterilization of water were assembled at Brentford and put through severe tests; no machine was accepted as fit for despatch to France until it had been worked successfully for twenty hours and had passed definite road trials. The men of the Army Service Corps required to run the pumps and work the motor plants were also sent to Brentford and were billeted there.

On 13th March, 1916, a demand for a second water company came from General Headquarters in France, in order to take advantage of any successful offensive by a large number of divisions during their passage through a sparsely watered area.

The headquarters and two sections of No. 1 Water Company proceeded to France in April 1916, and the third section followed a little later.

On the 8th May, 1916, Sir Douglas Haig reported that the equipment and working of No. 1 Water Tank M.T. Company

were generally satisfactory, and that the unit promised to be of great value, and asked for the mobilization of the second water company as soon as possible.

Headquarters and No. 1 Section of the latter left for France in June 1916, and the remaining sections in July 1916.

Water-sterilizing Machine employing Chlorine Gas.

Although the machines with Nos. 1 and 2 Water Companies worked well it was thought that they might be considerably improved. The labour of making the necessary solutions was not inconsiderable, and constant supervision was essential if good results were to be obtained. The machines had one great defect in that they were gravity controlled, and it was realized that if a better delivery of purified water was to be secured from the same weight of apparatus, a pressure system must be employed. Attention was directed to the use of chlorine gas; cylinders of this gas under pressure could readily be obtained from the Trench Warfare Committee, and if a means of accurately controlling the amount of gas added could be devised, it seemed that in these cylinders there was a sterilizing agent which could be easily employed with a pressure system. Experiments were commenced at the Imperial College of Science, South Kensington, under the direction of Professor Baker.

Very good results were obtained, and it seemed possible to dose water accurately under pressure with chlorine gas. When the experiments were at this stage, Mr. Menzies, of the United Water Softeners Company, informed the War Office that he had obtained the English rights of the Wallace-Tiernan gauge, which had been worked out in America and was in use there for the treatment of water with chlorine gas, and that he had constructed a machine under pressure for the sterilization of water by means of chlorine gas and dechlorination by means of liquid sulphur dioxide, employing the gauge for the dosage of the gases. The machine in many ways fulfilled the objects in view, and authority was consequently obtained to construct a chlorine gas water sterilizer for use in France. The machine was built at Brentford by Captain J. S. Arthur, assisted by the A.S.C. N.C.Os. and men, the necessary Wallace-Tiernan apparatus being supplied by the Water Softeners Company. As it was not certain that gases under pressure would prove effective in France, in consequence of heavy shaking and jolts on the bad roads, which might conceivably upset the working of the gauge, the machine was so fitted that solutions of

bleaching powder and sodium sulphite could be used if necessary in place of the chlorine and sulphur dioxide.

The new machine was sent to France in 1917 and was put into service in the field. It was found to work well and deliver about 1,200 gallons of sterilized water per hour. The Wallace-Tiernan gauge gave no trouble and the chloride of lime and sodium bisulphite had never to be used. Water treated with chlorine gas was much more palatable than water treated with chloride of lime containing a corresponding amount of available chlorine.

It was now possible to give exact instructions for the construction of a plant employing chlorine gas, and when a third water column was required in France, it was decided to equip the column with the new machines in place of the water sterilizers and poison eliminating plants supplied to the first and second water columns. The plants were constructed by the United Water Softeners Company, and each one was rigorously tested before despatch to France.

The plant was built up on a 4-ton Rike Locomobile lorry. The body of the lorry was specially constructed; the sides were let down to form a working platform, and in wet weather this platform was protected by means of canvas sides held in position by means of stretchers. The whole body was covered with a weather-proof roof. Next to the driver's cab there was a compartment which served as a small laboratory and from which the working of the plant could be controlled by chemical examinations. The plant consisted of the following parts :—

(*a*) Pumping unit.
(*b*) Filtering unit.
(*c*) Chlorinating unit and contact tank.
(*d*) Dechlorinating unit.

The pumping unit consisted of a 2½-h.p. Lister petrol engine, directly coupled to a 2-in. Roto-plunge pump. This was capable of pumping 1,200 gallons of water per hour through the plant normally, but for short periods a much greater volume could be pumped. The rate of pumping was regulated by a by-pass arrangement fitted to the pump.

The filtering unit was formed by a sand filter, with a filtering area of 9·6 sq. ft., fitted with distributors at the top and bottom, and valves so arranged that the water could be sent in either at the top for filtering, or at the bottom for backflushing and cleansing the sand.

There was also an arrangement by which a solution of

aluminium sulphate could be added to the water before it entered the filter, in order to render filtration more complete.

The chlorinating unit consisted of a standard Wallace-Tiernan direct feed type chlorinator, illustrated in Appendix B, 3.

By means of this apparatus chlorine gas in any desired amount, within the limits of the instrument, could be admitted to the water passing through the plant, and when once set the instrument would continue to deliver the desired amount of chlorine, irrespective of temperature and pressure changes, to which the liquid chlorine might be subjected.

The dechlorinating unit was a simple device whereby sulphur dioxide gas could be admitted to the water after it had passed from the contact tank and become sterilized. The sulphur dioxide could be adjusted so that the amount of chlorine required by the conditions governing the distribution was left in the water.

The control of the chlorine and sulphur dioxide was carried out in the small laboratory into which sample lines entered, and from which water could be obtained for chemical test at any moment.

A 2-in. hose pipe, fitted with a strainer and foot valve, was attached to the pump; two hose pipes were also attached to the effluent pipes, and one to the drain. On pumping, water passed through the pump, the rate being determined and controlled by means of the by-pass valve. At the same time a solution of aluminium sulphate could be admitted to this water. A portion of the water after leaving the pump passed to the water-jacket of the engine, and after cooling it was either returned to the pump or drained away.

The water then passed to the sand filter, and after filtration passed through the meter in the laboratory and then to the chlorination cylinder, where chlorine gas was administered by means of the Wallace-Tiernan chlorinator. After chlorination it passed to the contact tank, where sterilization was completed. From the contact tank the water passed to the dechlorinating cylinder, where sulphur dioxide was administered. From here it passed to the effluent hose pipes completely filtered and sterilized, and containing just the amount of chlorine that was desired. Arrangements were made for samples to be carried to the laboratory by means of small pipes, and also for filling the alum tank from time to time with water from the contact tank. The various portions of the plant were connected together by means of flexible joints and arranged so that they could be separately drained.

The instructions given to the chemists and N.C.Os. in charge of the various machines are detailed in Appendix B, 3.

As this new sterilizer delivered three times as much purified water as the machines with which Nos. 1 and 2 Companies were equipped, the War Establishment was modified in the case of No. 3 Company and No. 4 Company, which were subsequently mobilized. Each water tank company consisted of a headquarters with attached R.A.M.C., six sections for carrying water which were A.S.C. sections, and three sections which were R.A.M.C. sections for sterilizing water. The total number of vehicles was 324, of which there were 174 150-gallon tank lorries in the six carrying sections of the Army Service Corps and 30 500-gallon tank lorries. The headquarters of the company had 46 of the former and 9 of the latter type as spare water tank lorries. Attached to the headquarters section there were a R.A.M.C. captain as chemist, 2 staff-sergeants and sergeants, and 9 rank and file. With each of the three R.A.M.C. sterilizing sections there were one captain or subaltern as chemist, one sergeant and 9 rank and file. The plant for sterilizing consisted of two 30-cwt. lorries and one box van for chemicals with each sterilizing section, one 3-ton lorry for stores and baggage, four 3-ton sterilizers and one 3-ton laboratory. With the headquarters section there were also three 3-ton sterilizer lorries and one 3-ton laboratory.

CHAPTER IV.

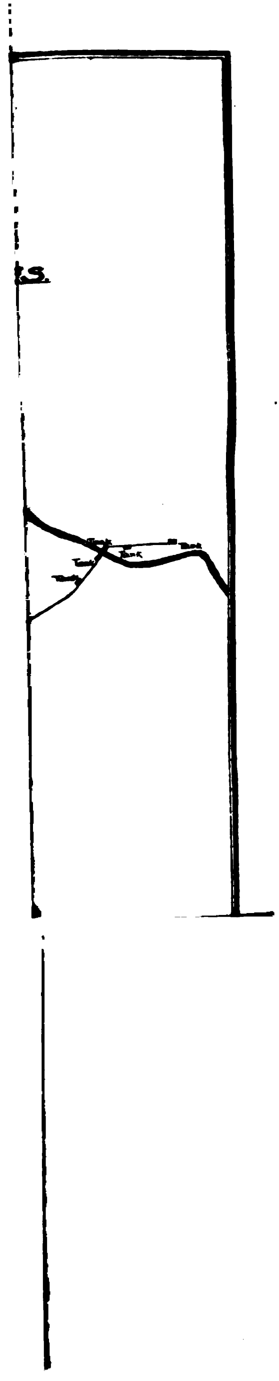
WATER SUPPLY IN FRANCE AND BELGIUM.

IN France and Belgium, owing to military necessity, sources of water had to be used which in ordinary circumstances would have been rejected, and the water problem mainly resolved itself into the removal of suspended material and the destruction of microbes likely to cause water-borne disease.*

In the early days of the war, owing to the comparatively small number of men concentrated in the various areas, the removal of suspended matter did not give rise to much trouble, as fairly clear water was generally available in sufficient quantity and sterilization was readily effected by means of chloride of lime.

From the commencement of the operations and up to the summer of 1915, the necessary water supply works were carried out by the Royal Engineer field companies under the C.R.E. of divisions, and the sterilization of the supplies provided by them was controlled by the medical officers of units and sanitary personnel. In the autumn of 1915, however, water supply schemes had to be prepared for a concentration of more than treble the number of troops; the water supply problem was quite beyond the scope of divisions, as the divisional Royal Engineers were more than fully occupied with trench work and the front system of defences, and so the schemes were prepared at corps headquarters, the Chief Engineer employing the Field Engineers to work out the details in definite areas. When the possibility of an advance eastward was entertained, General Headquarters, as already mentioned, took the matter up, and early in February 1916 a special officer and staff were attached to the office of the Chief Engineer of an army to deal with advance water supplies. Each corps appointed a water supply officer and detailed army troop companies to carry out the work, the schemes for corps area being submitted to the Chief Engineer of the army for approval. The corps proved too mobile a formation to deal economically with water supplies, and even with an army as the unit a good deal of overlapping occurred owing to the taking over of new areas and the

* In Egypt and Palestine another factor, salinity, occurred, but in France and Belgium excessively saline water was rarely encountered.



constant changes in army boundaries. But in spite of these difficulties a large number of power installations with rising mains up to five miles in length and more or less elaborate distribution systems was installed prior to the Somme offensive in July 1916.

The main idea of the systems adopted was to establish "initial water points" as far forward as safety would permit. Advanced pumping stations from which pipe-lines had been laid, in many instances up to the front line trenches, were ready and army troop companies were detailed to carry the pipe-lines rapidly forward and install "forward water points," consisting of canvas tanks laid on the ground near by-roads from which water could be pumped into tank lorries. It was in connection with these forward water points that the water companies, and to some extent the barges, though not so much as was anticipated, did such useful work. (Fig. 1.) While the Royal Engineers were clearing wells and preparing lines in areas recently occupied by the enemy, the sterilizers of the water company were able to form water points and deliver water to the tank lorries which carried it by definite road circuits to refilling points where the water carts from divisions received the water and distributed it to units. In other cases the sterilizers kept the tanks at the advanced water points filled with water, which was then delivered by advanced pipe-lines to the troops. In addition to this important work the chemists with the water companies examined the wells in new areas for poisons, and where the water was apparently potable determined the amount of chloride of lime required to sterilize a definite quantity of water; the amount so determined was generally inscribed on a notice board for the information of the water duty men.

In some areas where troops were temporarily concentrated for military reasons prior to or during an advance, a good water supply could not be found or the necessary works for supplying the amount of water required could not be erected in time. In these circumstances the water sterilizers were generally able to provide the water by clarifying and sterilizing water which otherwise would not have been potable.

When operations were in abeyance and temporary engineering works had been devised to meet the needs of the troops, the water companies were used to provide water for troops specially concentrated in back areas, for labour companies and even for road-making.

The following short description of the work of two of the

water companies gives a more detailed account of the water operations undertaken by these units.*

No. 1 Water Tank Company landed in France on 12th April, 1916, and was attached to the Fourth Army and stationed at St. Ouen. Here experiments were carried out on the time required to fill the tank lorries from the sterilizers and other water points. Some hand pumps (Dando) and motor pumps (Peco) were fitted to the 1-ton and 3-ton carrying lorries respectively and a full equipment of 2-in. hose was supplied to each lorry. It was found that there was then not sufficient transport for the carriage of the hose and other stores. This difficulty was overcome by fitting boxes of 30 cubic feet capacity between the hood and the tank of each of the 1-ton lorries.

A trial of the working capacity of the company was now arranged at Rainneville, and plans were worked out for the supply of 20,000 gallons of water per day to each of the two divisions in rest areas. The tests lasted for a week and gave invaluable data as to running difficulties, refilling times, best methods of loading and unloading and the total water that one section could deliver daily for different distances. The sterilizers were used with great success and altogether the trials gave universal satisfaction. Most of the army, corps and divisional staffs took an active interest in the trials and reported favourably on the work of the company. As a result of the trials it was found necessary to increase temporarily the carrying capacity of the unit by the addition of 144 3-ton extemporized tank lorries.

The work of the company now commenced in earnest. Sections were sent to places where water was most urgently required during concentration of troops on the Somme. Lorries were widely distributed, as the whole of the Fourth Army requirements had to be met. The work done was of a dual nature, water sterilizing by the sterilizing machines and water carrying by the tank lorries.

Frequently some of the water sterilized was delivered direct into water carts or other receptacles, and some of the water carried was not obtained from the sterilizing machines but from stand-pipes erected by the Royal Engineers, and fed by pipe-line installations. In many instances the water tanks saved a critical situation during the Somme battle by carrying water from the water points in the rear into the concentration area, where the engineer pipe-lines had been hit

* The account is taken from the reports of the R.A.M.C. officers attached as chemists to the water companies.

by shells, or otherwise put out of action. This occurred at such places as Fricourt, Montauban, Longueval and Bécourt. On other occasions the sterilizers were able to establish a water point from a dirty stream or marsh where it would not have been possible for the engineers to put in a pipe-line, or from a well supply of good quality such as was found at Etineham, Allonville and Pontainville, Méault and Dernancourt. It was soon found that the sterilizers often could not get near enough to the water source ; in such places auxiliary pumps were installed, and the water was pumped into a canvas tank of about 2,000 gallons capacity. These canvas tanks and special pumps (Pelaphone) were of great use throughout the campaign, and became a permanent part of the equipment of the company. During the Somme battle the tank lorries also carried water for horses, locomotives, baths and road-making, in addition to sterilized water for drinking.

The lighter 1-ton lorries often went very close to the fighting line and were almost continually in the shelled zone. They were able to take water up to points where the unrepaired state of the road was not suitable for heavy traffic. The 3-ton lorries were invaluable where large volumes of water were urgently required, as, for example, when a sudden concentration of men took place in an area where no pipe-line had been installed. The sterilizers constituted additional water points and the chemists did much analytical work on the well supplies for the corps to which they were attached. The total water carried by the company during the Somme battles was over 11,000,000 gallons.

In March 1917 the company came under the administration of the Third Army, the chemists were attached to the various corps and examined many samples of water from wells in the evacuated area for poisons and other contaminations.

On 17th June of that year Captain Stickings with eleven other ranks proceeded to the Belgian sector with two sterilizers and one lorry for the elimination of poisons. Experiments were carried out at Bulscamp, and Belgian mechanics and pharmacists underwent a course of training under him there. The instruction lasted ten days, and the lorries were inspected by the Chef d'Etat Major, the Chef du Service de Génie, and the Chef du Service de Santé. The two sterilizers were then handed over to the Belgian headquarters, and the British personnel, together with the lorry for the removal of poisons, rejoined their company in France on the 29th of the month. After a month's rest at Hesdin for refitting, the company

moved into the Second Army area, where the water was bad compared with that met with on the Somme and the Arras front. It was highly coloured, heavily polluted, and had much fine clay in suspension. The precipitate formed after treatment was driven right through the coarse sand in the filters when the pumps were working at the rate of 400 gallons per hour. Captain Stickings found that pre-sedimentation in the canvas tanks already mentioned was necessary in order to remove the large amount of suspended matter in the water, alum and lime, as required, being added. He also recommended that 8 in. of dune sand should replace the 20 to 30 grade sand in the sand filter, and that the permutit filter should also be filled with sand and run parallel with the first filter. These recommendations were adopted, and a perfectly clear filtrate was obtained.

During the Passchendaele offensive in August 1917 the lorries were working within a mile of the front line. Water was carried from advanced water points and delivered into stationary tanks and canvas dams. In September, the water in Dickebusch lake became badly contaminated ; the whole area feeding the lake, which is an expanse of several acres of water, had become a concentration area of camps and horse lines. The whole of the Dickebusch supply was purified by the sterilizers of No. 1 Company, assisted by a section of No. 3 Company, until a satisfactory system of filtration through sand was established.

On 9th October, 1917, Nos. 1 and 2 Sections left for Albert and worked with the Third Army during the Cambrai offensive. Subsequently, No. 2 Section went to the First Army, and Headquarters and No. 3 Section to the Fifth Army.

During the German offensive in 1918 all the water-carrying vehicles were in great demand to supply the retiring troops with water, and several of the drivers actually assisted in holding trenches during the night time. During the second German offensive in the northern area much useful work was done in the back areas ; many wells were examined by the chemists, and a little later the area covered by the carrying tanks and sterilizers was nearly 2,000 square miles.

The company next took part in the advance from Amiens on 8th August, 1918. The water-carrying lorries and the sterilizers followed rapidly behind the troops, supplying water wherever required. A system of canvas reservoirs was employed. The reservoirs were filled by the carrying lorries, which moved forward in conformity with the advance of the

divisions. Sterilizers were at work at various points on the rivers Somme, Ancre, Avre, and Luce. In one instance a sterilizer was working at a point on the Luce within eighteen hours of the evacuation of the position by the enemy. The men worked often for several days with only a few hours' sleep at irregular intervals. The sterilizers were practically the only important water points in the forward areas for several days until the engineers laid pipe-line systems and got wells in working order.

On 22nd August, 1918, No. 1 Section worked with the Third Army in the advance to Bapaume, water points being again established.

During the general advance in September the sterilizer and water-carrying work was very heavy as the troops advanced over comparatively waterless districts of Picardy. A record for water delivered by the company was reached during the week ending 6th September, 1918, on which date 500,000 gallons of water were sterilized, and 1,250,000 gallons of water were carried. After the Hindenburg line had been broken sterilizers were immediately got into position on the St. Quentin canal. It was feared that the canal water might have been poisoned, but this was found not to be the case. During the month of November the sterilizers and carrying lorries followed up advancing troops and played an important part in the success of the Fourth Army operations. After hostilities ceased on 11th November, 1918, a flying section of No. 1 Water Company accompanied the Fourth Army. Up till then the company had sterilized 5,500,000 gallons of water and carried 35,500,000 gallons of water since its arrival in France.

No. 2 Company landed in France towards the end of June 1916, and joined the Fifth Army in the northern part of the Somme area.

In the autumn and winter of 1916 the wells in practically every village in the Fifth Army area, from Beaumont-Hamel, Auchonvillers, Martinsart, Albert and Pozières in the forward area, to Doullens, Beauquesne and even farther back, were mapped, tested and labelled.

After the German retreat of February 1917 the unit was divided between the Fourth and Fifth Armies. In the Fourth Army area sterilizers were working at Peronne, Ryaulcourt, and many other places in the newly occupied area. In the Fifth Army the sterilizers were at Miraumont, one of these vehicles being the first of the heavy lorries to cross the new wooden bridge over the Ancre.

About May 1917 the whole unit was brought together again and sent north in time for the concentration in the Second Army area before the battle of the Messines Ridge. Here one sterilizer was working on the River Douve, just under the ridge, and for some days after the advance was by far the most forward source of drinkable water. The light Garford tank lorries were also much used at this time. Nearly every vehicle in the section was hit by shell fire, and the lorries were taking water almost up to the front line the evening before the offensive commenced. The unit continued working in the area during the remainder of the year, when practically every machine was concentrated at Haringhe, where the newly erected waterworks on the Yser had failed to produce clear water. The sterilizers of the unit kept the supply going till better methods were in operation.

On the commencement of the German offensive in the spring of 1918 the unit was first concentrated at St. Riquier, near Abbeville, where half remained, while the other half returned to the Ypres salient.

Important work was carried out by the sterilizers of the company in the Hazebrouck area after the German offensive in April and May 1918, as the British troops had been driven back into an area which had not previously been provided with a drinking water supply for a large number of troops.

Later, the unit was broken up into several detachments, and served in four different army areas.

Its sterilizers were then at work in front of Arras at the commencement of the allied offensive in August 1918, on the canal near Havrincourt Wood when the offensive which resulted in the capture of Cambrai began, on the River Serre near Le Cateau, and finally at Le Quesnoy, where three sterilizers were installed and busily at work on the day the armistice was signed.

Shortly after this the unit was concentrated again in and around Lille, with headquarters at Marcoing, and afterwards proceeded with the Second Army to Cologne, to form part of the Army of Occupation.

Many millions of gallons of sterile water had been delivered by the sterilizers of the company during the operations in France. Apart from the work done by the sterilizing lorries the Royal Army Medical Corps personnel had also frequently been employed on other work connected with the purification and control of water supplies.

After the German retreat the fear that the water supplies had been poisoned with arsenic was great. A laboratory was consequently started as a testing point, first at Mailly and later at Bapaume, and the Royal Army Medical Corps non-commissioned officers scoured the country testing wells and bringing samples for more accurate work to it. A similar laboratory was instituted in the Fourth Army area at Framerville.

Filtration Barge Units.

Although there was no opportunity during the war for working the filtration barge units to the limit of their capacity and to the extent to which it was thought they might be required, they were put to very considerable use. Their output of purified water amounted, in fact, to 55 million gallons.

Nos. 1 and 2 barge units were employed for months at Jesus Farm and Fort Rompu, a few miles from Erquinghem on the River Lys, in purifying water and pumping it to a pipe-line. In 1916 two of the barge units were taken by sea to the Somme, and were employed for several months at Froisey, being connected there with a pump-line. Subsequently, one of the units was taken to Peronne. When no longer required on the Somme both units were brought back to the northern waterways in May 1917.

In July 1917 when British troops occupied the Nieuport sector on the Belgian coast, where the water supplies were insufficient, the barge units rendered considerable service, although it was not possible for them to work on the Nieuport-Furnes canal, owing to the proximity of this waterway to the sea and its consequent salinity. The units therefore had to be stationed some distance back at Bergues. The number of water tank barges was largely increased, and a filtered water barge service was maintained continually from Bergues to the various points along the Nieuport-Furnes canal.

The barge units also supplied the allied troops in this area; and during the operations in the summer of 1917 two were working for the French on the River Yser at Rousbrugge.

In April 1918 when the Germans advanced across the Lys, two units stationed at Fort Rompu had to be abandoned, as it was found impossible to bring them back owing to the temporary bridges which had been thrown across the river by the retreating troops. Explosive charges were, however, placed on board, and one filtration barge was blown up and the other partially destroyed.

Arrangements for supplying Water to Casualty Clearing Stations in the Advance of 1918.

When a casualty clearing station moved, 2,300-gallon canvas tanks were in charge of the officer commanding, and on arrival at a new site the C.R.E. of the army concerned made arrangements for whatever constructional work was necessary. The tanks were filled with sterilized water by the carrying section of the Water Tank Company operating in the area.

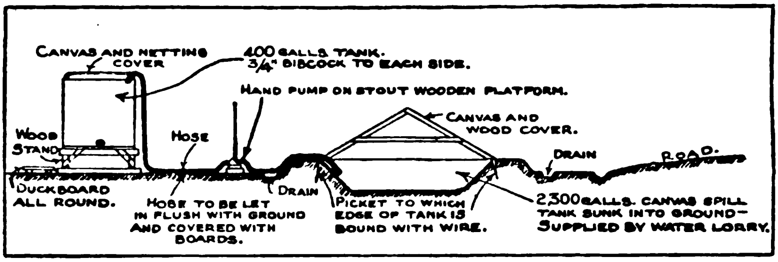


Fig. 2.—Rapid method of supplying water for a casualty clearing station.

The average requirements of the casualty clearing stations, as noted in the Second Army area, amounted to 5,000 gallons per day.

Small Filters for use in the Trenches.

During the later stages of trench warfare, owing to the development of intensive barrages, it was often difficult for short periods to maintain the supply of pure water to the front line, and there was the risk that men would resort to the water in shell-holes, often polluted by excreta and possibly poisoned by enemy poison gas. Consequently the medical department of the War Office considered that a small filter suitable for pack carriage on man or animals would be of service to the troops.

M. Desrumeaux, a French engineer who was consulted, suggested that a useful filter could be made on the lines of the system adopted in his water-cart, using silex as the medium for filtration. He prepared a design for a mule pack filter, which after some modification was tested at Brentford and gave good results. (*See* Appendix B, 5.)

A smaller filter on similar lines suitable for carriage by a man was then designed and proved satisfactory.

These small filters were, however, not used, as owing to the German offensive and the subsequent development of a war of movement they were not required.

Testing of Water poisoned by Gas Shells.

The probability of the poisoning of water supplies by gas shells was considered in 1918, and a memorandum on the subject was issued by the Director-General Medical Services in France.

Of the gases used the only ones that had to be considered, from the point of view of poisoning of water supplies, were the arsenic derivatives (Blue Cross and Green Cross, III) and dichlorethylsulphide (Yellow Cross). Lachrymators, including chlorpicrin, could at once be detected by their smell and their effect on the eyes.

All the gases, with the exception of ethyl carbazol and diphenylcyanarsine, contained chlorine or bromine, and all the lethal gases, with the same exceptions, were decomposed by water at varying rates to give hydrochloric acid or hydrobromic acid. The rate of decomposition of chlorpicrin was practically negligible, but this gas was always used with diphosgene, which readily decomposed to give hydrochloric acid. Water samples therefore had first to be examined for chloride and bromide, and if the amount was very high the presence of poison gases was to be suspected. Diphenylcyanarsine gave hydrocyanic acid with water, and the test for hydrocyanic acid would determine the presence or otherwise of diphenylcyanarsine.

With regard to the test for the presence of arsenic, the ordinary Marsh test on a water sample would not as a rule show the presence of organic arsenic. It was necessary therefore to transform the organic arsenic into the inorganic form. To do this 1 litre of the water was taken, 1 c.c. of strong nitric acid added and evaporated to dryness on a water-bath. The residue was transferred to a long-necked hard glass (Kjeldahl) flask, 10 c.c. of concentrated sulphuric and 1 c.c. of concentrated nitric acid added, and heated over a gauze and Bunsen flame, with the flask in a slanting position to avoid loss, for two hours, or longer if the solution had not become colourless in that time. After the solution had cooled, it was diluted with distilled water to about 100 c.c., and sulphur dioxide was passed through it for fifteen minutes to reduce arsenic acid to arsenious acid. The excess of sulphur dioxide had then to be completely boiled off. The solution was then made up to 250 c.c. and 10 c.c. or more if necessary tested by the Marsh test.

It was not possible to determine the limits of arsenic allowable but diphenylarsenious oxide appeared to be considerably more poisonous than arsenious oxide and therefore, if any arsenic

were found, it was safest to condemn the water. Diphenylchlorarsine and cyanarsine were hydrolyzed by water almost completely in the presence of large amounts of the latter to give diphenylarsenious oxide:

$$2\,(C_6H_5)_2AsCl + H_2O = [(C_6H_5)_2As]_2O + 2HCl.$$

Although this oxide is only slightly soluble in water to the extent of about 20–30 milligrams per litre at the ordinary temperature, the amount was toxic, and in addition a certain amount of oxide might be present undissolved in the solid form.

No direct test was available for detecting the presence of dichlorethylsulphide, but the following method was adopted to indicate its presence. One litre of the water was evaporated to complete dryness on the water-bath. The residue was extracted with dry ether, the ether evaporated off on a water-bath and the residue, if any, tested for sulphur by fusion with sodium and treatment with sodium nitroprusside in the usual way. The presence of sulphur indicated the presence of dichlorethylsulphide or its decomposition products. If, in addition, the chlorine in the water was very high, contamination with yellow cross gas was highly probable. The extraction with ether was necessary to separate organic from inorganic sulphur (sulphate), both of which are normally present.

Dichlorethylsulphide is hydrolyzed by water to give thiodiglycol and hydrochloric acid, both of which are harmless:

$$(C_2H_4Cl)_2S + 2H_2O = (C_2H_4OH)_2S + 2HCl.$$

This goes to completion if a large amount of water is present, and practically at once on boiling.

Poisoning from water containing yellow cross gas, especially after boiling the water, was therefore extremely unlikely.

The poisoning of large masses of moving water, rivers and streams by gases of any kind was improbable owing to the enormous amounts of poison required. Stationary water supplies, such as reservoirs or wells and particularly shell-holes filled with water, could, however, readily be poisoned, especially with the arsenical compounds.

Arrangements when Pipe-lines were not available.

During the advance in 1918, when no springs, artesian wells or pipe-lines were available, crude stream water had often to be used, and to purify this supply a portable plant, consisting of two pumps, two canvas tanks, and two mixing boxes, was devised (Fig. 3).

The water was sedimented by means of alum in the first tank, and the clarified water subsequently treated with chloride

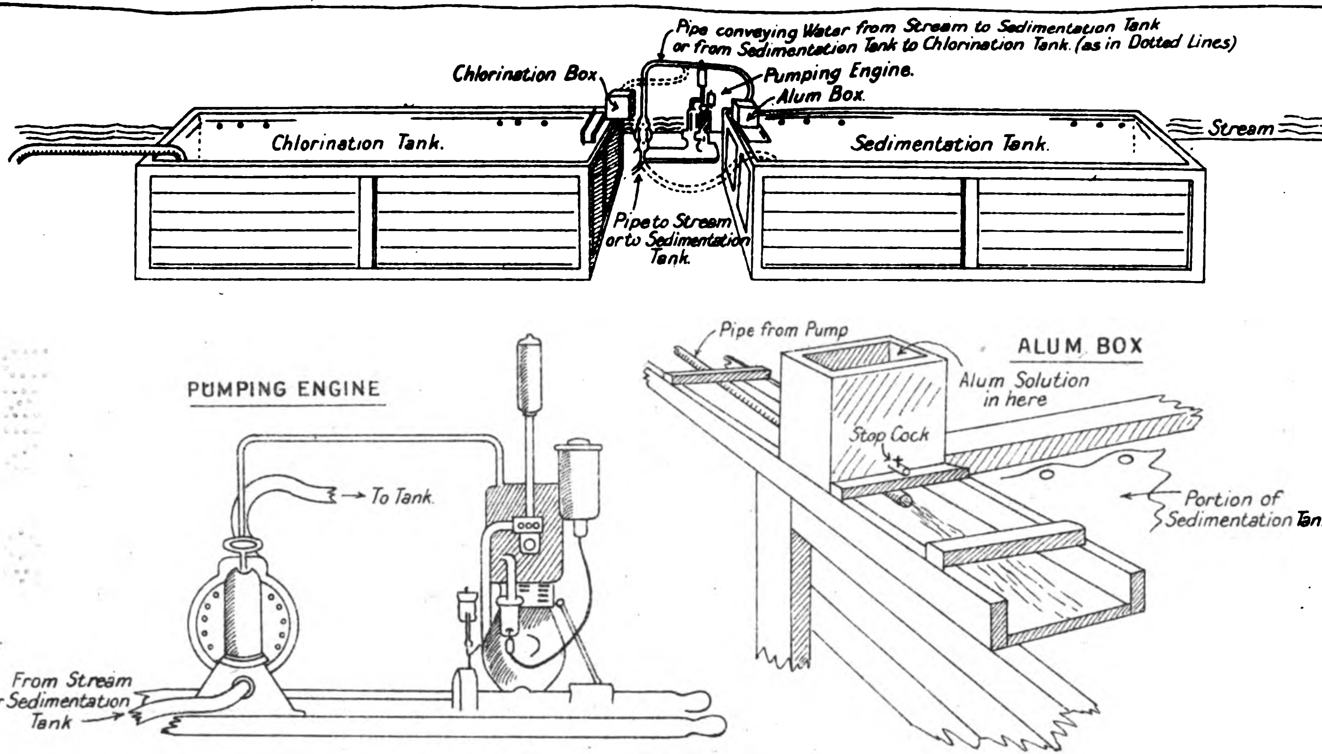


FIG. 3.

PORTABLE PLANT FOR PURIFYING WATER DIRECT FROM STREAM.

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of lime. The time taken by the engine to fill one of the tanks was first determined, and then a solution of alum was prepared and put into the first mixing box, which had a bibcock feed, so that the supply of alum could be regulated. The alum solution was then allowed to flow into the first or sedimentation tank, the feed being so regulated that by the time one tank was full the whole of the alum solution would have been evenly distributed in the raw water. Sedimentation was allowed to take place for six or seven hours, according to the turbidity of the raw water. The untreated water and the clarified water were then tested with the water sterilization test case to determine the amount of chloride of lime required for the clarified water, and the improvement in the water produced by the clarification. The measures of chloride of lime required for the clarified water were made into a solution and placed in the mixing box on the chlorination tank, and the feed regulated as in the case of the alum box. The chlorinated water was then left for one hour, when it was pumped by means of the second pump into the water-carts. By increasing the number of tanks a constant supply of purified water could be maintained.

General Conclusions.

As a result of experience gained in France, the general conclusions on water supply organization may be summarized as follows :—

(1) For the sterilization of water by units, chloride of lime, controlled by the use of the test case, has proved efficient in the hands of the sanitary personnel.

(2) The appliances for the purification of water by units should be as perfect as possible. With modern gunfire, roads are often rendered impossible for motor traffic for some hours, but horse-drawn vehicles and pack transport could, as a rule, reach the units. A good water-cart for each unit was therefore essential. For most water supplies the means of purification provided by the Mark VI and VII carts was sufficient.

In stationary or trench warfare a filter, such as the small or mule pack filter, would give additional security against water-borne disease, as such a filter could be made available in case of necessity for the purification of water actually available in the trenches.

(3) Water columns provided with motor purification plant of the chlorine gas type proved of great service, especially during an advance into country devastated by the enemy,

as they enabled water to be delivered to the troops within a very short time after the capture of the ground, while the Royal Engineers were preparing pipe-lines. They also enabled troops to be concentrated for short periods in areas where permanent supplies were deficient or required special treatment to render them potable. The large delivery of water (1,200 gallons), considering the small standing space occupied, was also important when water points were being established on a main road. The water delivered by the chlorine gas plant was more acceptable to the troops than that treated with chloride of lime. The working of the plant was easy, and the provision and carriage of a large quantity of a variable substance like chloride of lime was thus obviated. The risk of employing cylinders of liquid chlorine was very small. When forming water points it was found that the delivery of 1,200 gallons per hour was sometimes not required, and the plants were not worked to their full capacity. If some smaller plants of similar construction to those provided for use in India, but delivering about 600 gallons per hour, had been included in the water column, they would have proved most useful; the weight of the plant could thus be much reduced and they could get forward more quickly over badly repaired roads and weak bridges.

(4) The water-purification plant on barges did not seem to fulfil the rôle anticipated. The units were too large and had not the same freedom of movement as motor plants on roads. They were, however, useful when large bodies of troops were concentrated in the neighbourhood of rivers or canals, but chiefly when these formed the main sources of supply and the military movements were limited to comparatively short distances from them. In circumstances such as existed in France and Belgium, motor water columns were more useful than the barges. Four chlorine gas plants gave the same delivery as one barge, and were much better adapted to the conditions of modern warfare. They were more mobile, could be readily concentrated or dispersed as occasion required, and were not so easily destroyed by aerial attack.

(5) With regard to general supervision and control it was found advisable to have a standing Water Committee at General Headquarters composed of representatives of the General Staff, the Chief Engineer, the Director-General Medical Services, and the Director of Transport; and also with each army a Water Committee of similar composition, with whom the officer commanding and senior chemist of each water company or column should be in direct communication.

CHAPTER V.

WATER SUPPLY IN EGYPT AND PALESTINE.

WHERE the largest concentrations of troops occurred, namely, in the vicinity of the principal towns—Cairo, Alexandria, Ismailia, Port Said and Suez—extensions of the town water supply met the requirements of the troops. But as nearly all the land in the Nile Delta is irrigated, heavily polluted, and swarms with mosquitoes it was necessary to camp the troops in Egypt as far as possible on vacant desert land, and also to form camps outside the areas served by the water companies. There were three sources of supply for these: deep well bores, Nile water from the irrigation canals where boring was not likely to be successful, and condensers where all other sources failed. At Mena Camp, near the great pyramids of Gizeh, as many as 30,000 men were supplied with drinking and washing water from a 6-in. tube well sunk in the camp to a depth of about 120 ft. At Wardan on the edge of the desert at Khanka, 40 miles north-west of Cairo, at Tel-el-Kebir, and at Belbeis, tube wells, averaging 100 ft. to 150 ft. in depth were sunk. At Aboukir, north-east of Alexandria, but beyond the limits of its water supply system, at Abu Sueir, and along the Suez Canal it was necessary to instal filter plants and purify water from the Sweet Water Canal. At Moascar Camp, near Ismailia, a filter specially for the use of the camp was installed to supplement the town water supply. At Sollum and Mersa Matruh on the Mediterranean coast, west of the Delta, condensing machinery was erected. Water was also obtained from shallow wells dug in the sand on the seashore.

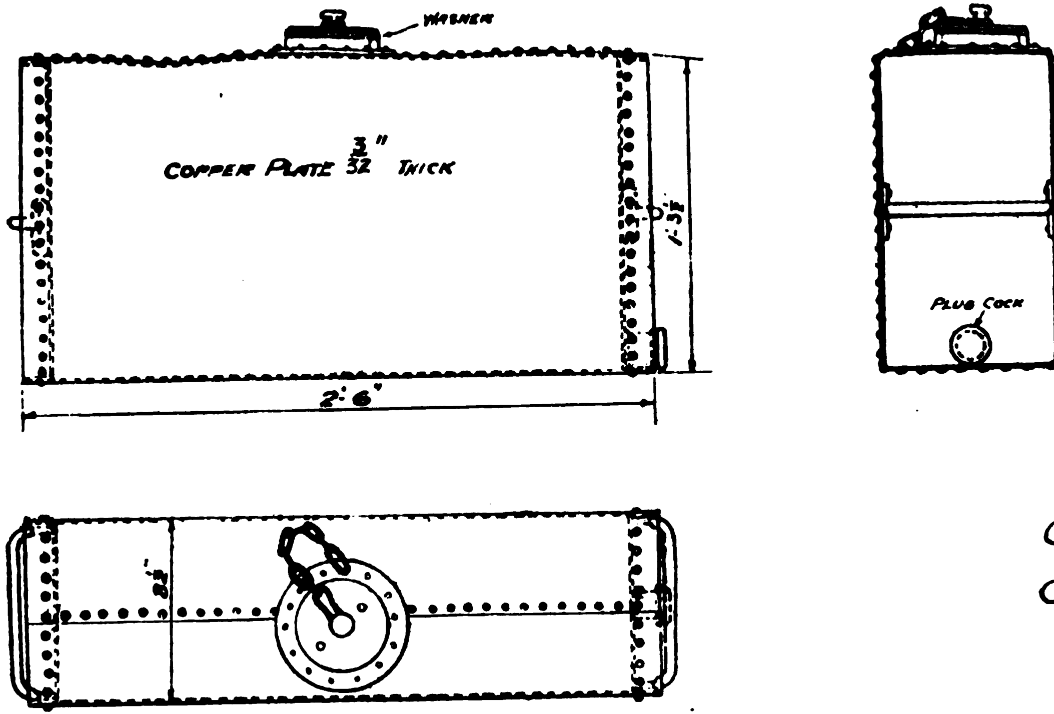
The Suez Canal Area.

The only reliable source of drinking water in the Suez Canal area is the Sweet Water Canal, which flows from the Nile to Ismailia and thence south to Suez and north to Port Said. This water, however, is unfit for consumption unless purified. On the east side of the canal beyond Suez the wells of Moses yield a supply of water, but it is brackish and unpalatable. There were also a few scattered wells of brackish water in the Sinai desert, some rock cisterns in the Sinai foothills, while further north, in the Katia Oasis, water of questionable quality

could always be obtained from shallow wells. The Turkish army which attempted the invasion of Egypt managed to subsist on these supplies. British troops holding defence posts from Suez to Port Said relied on the water supply system which had been installed by the Suez Canal Company at Suez, Ismailia and Port Said. This water was distributed to the various garrisons on the banks of the canal by water boats and barges, and by a water tank steamer. At all posts tanks were provided to store two days' supply of drinking water.

In November 1915 it was decided that "the defence of the canal must be taken up seriously and in depth." It was considered that whatever scheme of defence the troops detailed to hold the Suez Canal might adopt, certain of the existing bridge-head posts would have to be developed to provide water-supply systems which would lead eastward into the defences. If drinkable water in sufficient quantity could be obtained by sinking deep tube wells, this was obviously the simplest and most economical plan. Experimental borings were made at selected posts east of the canal, but although these extended from 75 to 200 ft., only salt water was obtained. It was, therefore, decided to develop the only existing known source of supply, the Sweet Water Canal. While this work was being carried out outlying posts were occupied, and before the pipe-line reached them the troops were supplied with water carried in fantasses placed on camels; each camel carried two tanks of 12 gallons capacity, and weighing 180 lb. when full (Fig. 1). At Ferdan and Ballah new branch canals were excavated to bring the fresh water to the west bank of the Maritime Canal. There were nine points at which water was purified for the outposts on the east of the Suez Canal, namely, Quarantine, El Shatt, El Kubri, Shallufa, Serapeum, Moascar, El Ferdan, El Ballah and Kantara (Fig. 2). The Quarantine post was supplied with filtered water from the Suez town supply, which, after purification, was delivered by water boats and pumped into tanks or storage reservoirs. From it 50,000 gallons of water a day were pumped to the posts. In case the supply by boat failed a condenser was erected capable of delivering 8,000 to 10,000 gallons per day.

The El Kubri and El Shatt supply was obtained from the Sweet Water Canal by means of a 6-in. pipe, fitted with a strainer of wire gauze to exclude snails, which delivered the water into two circular sedimentation tanks, each holding 32,000 gallons. They were constructed on the maze principle and could be used alternately. From the tanks the water was



COPPER FANTASSE
CAPACITY 12 GALLONS

FIG. I. COPPER FANTASSE.

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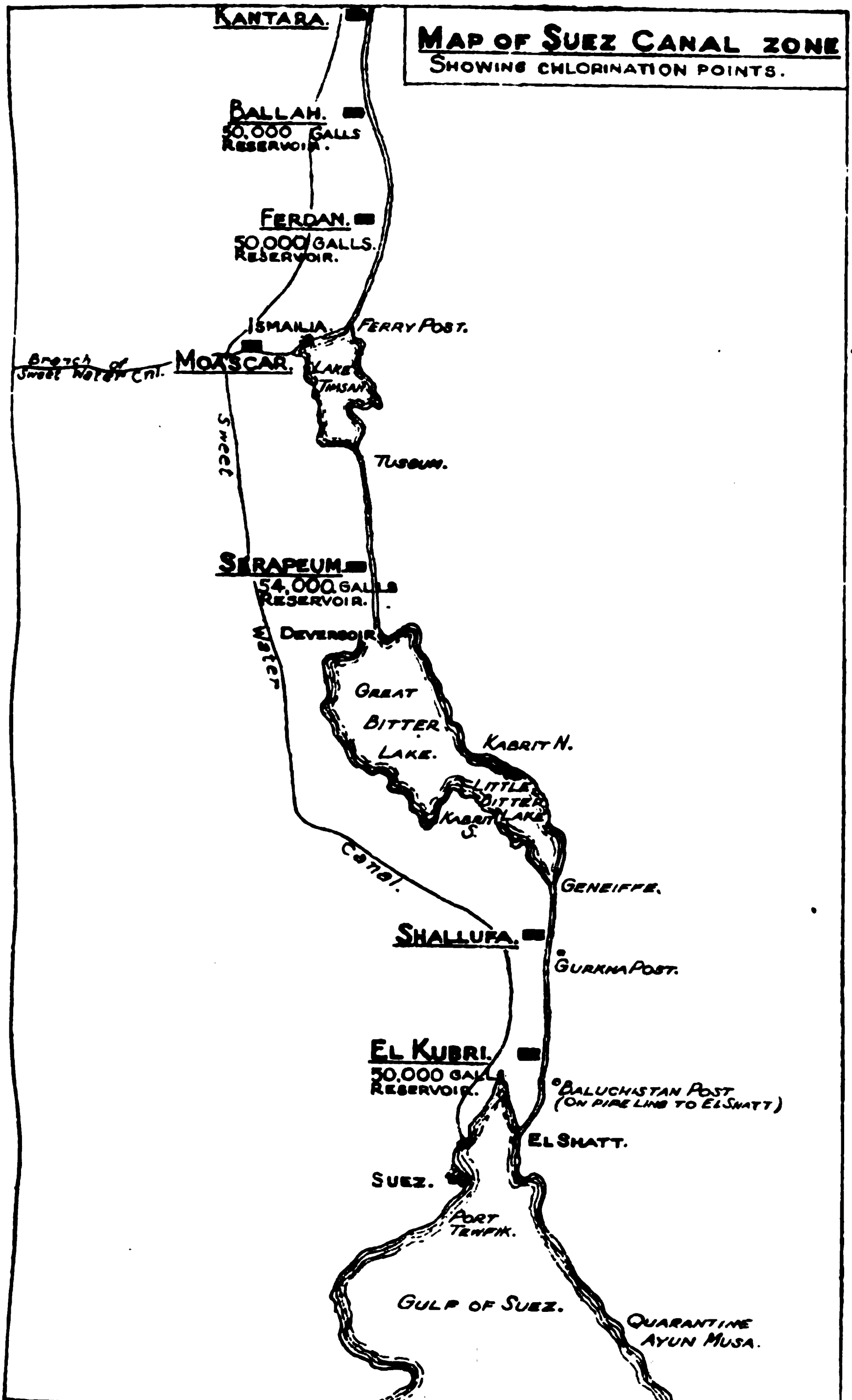

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FIG. 2.

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pumped into four mechanical filters of the Jewell type, each having an output of 5,000 gallons per hour (Fig. 3). The water took twelve hours to pass through each tank. Sulphate of alumina was added to the water before entering the settlement tanks. After filtration a solution of chloride of lime was added to the filtered water, and 700 gallons of chlorinated water were collected in a tank and used for washing the filters. The main body of filtered and treated water passed by gravity to the east side of the canal through a 6-in. inverted syphon pipe, and was stored in a 50,000-gallon reinforced concrete reservoir, and then pumped to El Shatt and to railhead, where there was a similar reservoir supplying the adjacent posts.

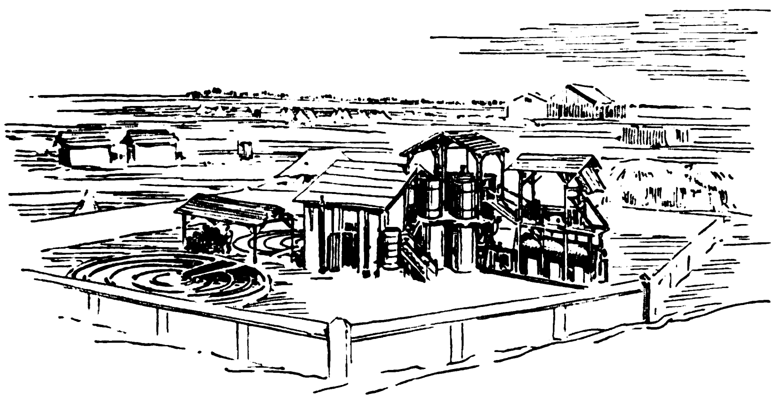

Fig. 3.—Sketch of water supply installation at Ferdan, December 1916.

The Shallufa supply was also obtained from the Sweet Water Canal and the arrangements for storage and purification were similar to those for El Kubri and El Shatt.

The supply for Serapeum was derived from the Sweet Water Canal by means of a branch which terminated at the Suez Canal, and the water was treated in the same manner as that for El Kubri, El Shatt and Shallufa.

The supply for Moascar was obtained directly from the Sweet Water Canal and was treated on lines similar to the above, except that in place of the Jewell filters there were three sand filters, each capable of filtering 40,000 gallons a day. The sand filters had to be scraped every two or three weeks when the water was in bad condition, but usually lasted five or six weeks; one filter was generally out of action for cleaning purposes and the remaining two delivered 80,000 gallons a day.

The Ferry Post water was obtained from the Ismailia town supply. The water for El Ferdan was taken from a branch of the Sweet Water Canal. At a point about several hundred yards above the intake sulphate of alumina was added to the water in the branch canal and apparently gave good results. The supply, storage and filtration arrangements were similar to those at El Kubri; the water was treated with sulphate of alumina before and after settlement and chloride of lime was added to the filtered water. The general arrangement of the water supply at El Ferdan is shown in Fig. 4 and the details of the plant in Fig. 5.

The arrangements for the water supply to El Ballah were on similar lines to those at El Kubri, the water being derived from a channel which had been cut from the Sweet Water Canal. There were three vertical mechanical gravity filters and the water was treated with alum and chloride of lime, as already described.

El Ferdan and El Ballah had also a piped supply from Ismailia, and Kantara had a similar supply from Port Said. Prior to 1916 these formed the main supply to troops on the east bank of the Suez Canal; troops on the west bank were supplied by water boats. These supplies were again taken into use in 1919 when the filters were closed down.

There were two purification installations at Kantara, an old 6-in. installation and a new 12-in. installation. The water was obtained from the Sweet Water Canal, passed into settlement tanks and was then filtered through six mechanical filters in the 6-in. and ten of large size in the 12-in. installation. A feature of the Kantara plant was the introduction of an automatic fool-proof arrangement by which the filtered water was run to waste for twenty minutes after the filter had been cleaned, thus ensuring that the scum on the filter became reformed and the filter had reached its full efficiency before the water was allowed into the reservoirs. Two of the old installations were of the Bell type and the remaining four of the Jewell type. They were capable of delivering 186,000 gallons daily. The filtered water was conveyed in two 6-in. pipes under the Suez Canal to storage reservoirs with a capacity of 500,000 gallons on the east side, and thence was pumped to Romani. The filters of the new installation could deliver 500,000 gallons daily.

The Kantara-El Arish 12-in. pipe-line was designed to supply water between Kantara and El Arish and, along the route of 96 miles, pumping stations were arranged at Kantara, Romani, Bir el Abd and Mazar.

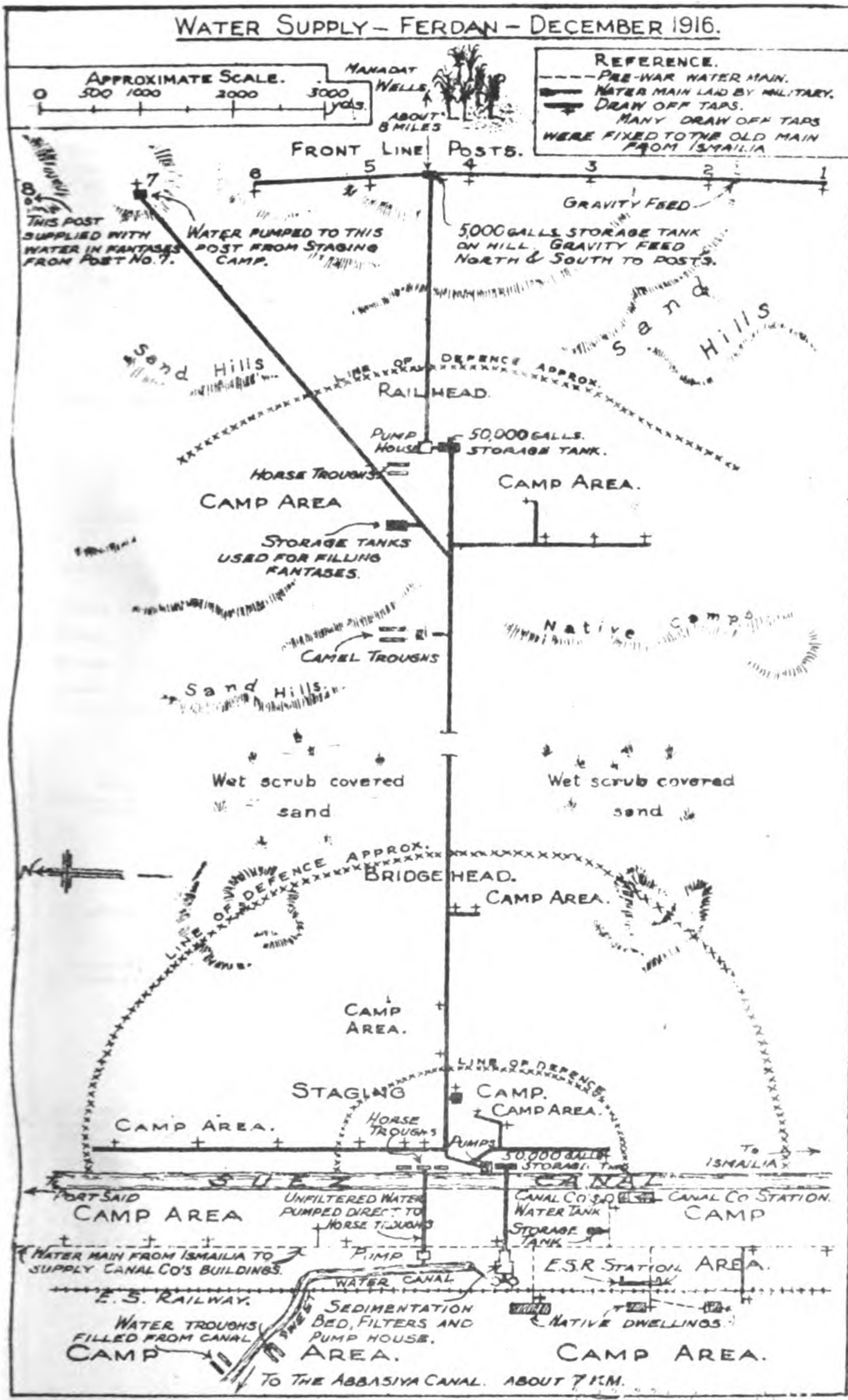

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FIG. 4.

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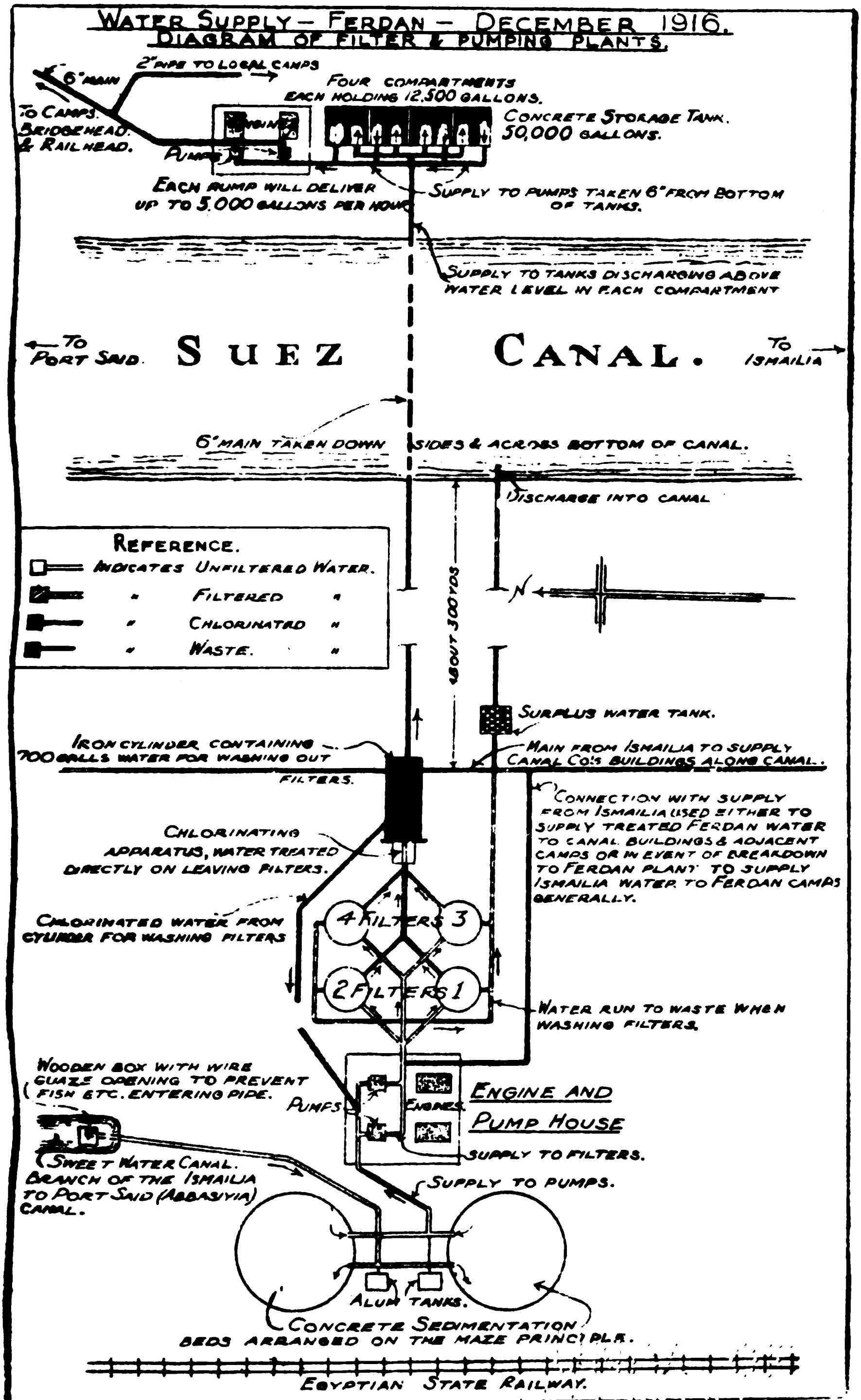

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FIG. 5.

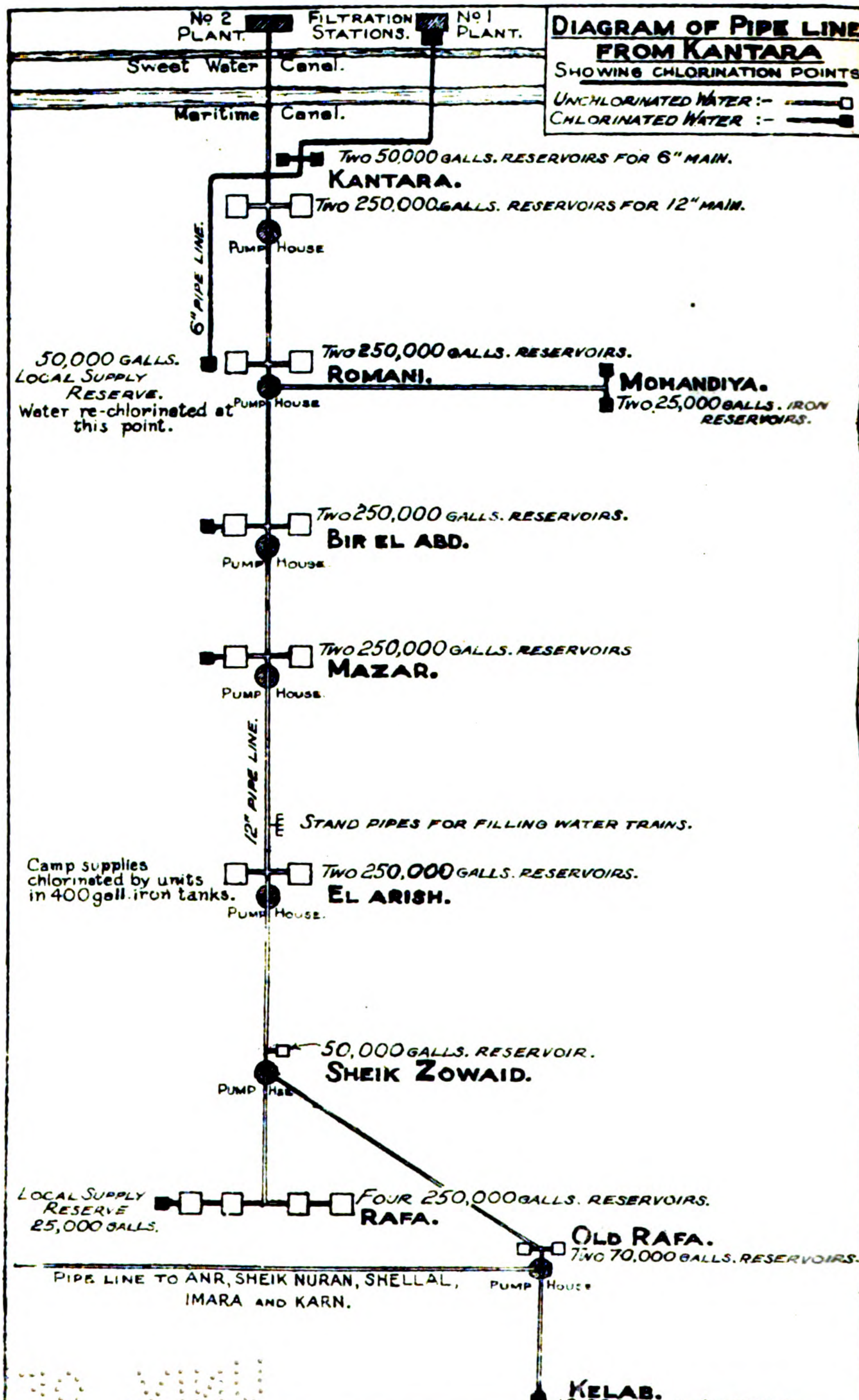

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FIG. 6.

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At Romani there were storage tanks having a capacity of 500,000 gallons, and the water was pumped 21 miles to Bir el Abd, where two reservoirs, each of 250,000 gallons capacity were erected ; similar ones were constructed at Mazar. (Fig. 6.)

The water of the Sweet Water Canal and its branches was seriously polluted at all the nine points from which it was taken, as above described, and constant supervision of all the purification plants was imperative. After treatment the water was as a rule quite clear and tasteless. The standard of bacteriological purification obtained was not so high as that fixed by sanitary authorities in the United Kingdom, but there were no cases of sickness which could be directly attributed to the drinking of water. The best results were obtained at Moascar, where slow sand filters were in use.

Chloride of lime was added to the water at all the installations continuously, with the exception that for about six months, from April to October 1916, it was omitted from the water supply from Serapeum. After examining the bacteriological records at the various installations, it was decided that on no occasion should water be supplied without being chlorinated.

At Abu Sueir the water was not sedimented as elsewhere, but a sump was dug some 20 yards from the Sweet Water Canal and the seapage water collected. So satisfactory was the result that the water direct from the sump did not need further purification other than chlorination. The arrangements at Abu Sueir, where only two air squadrons had to be supplied, was in the nature of an experiment and showed that the erection of a filter plant was unnecessary, provided that arrangements for chlorination were made. The method, however, was only applicable for the supply of water to small bodies of troops. The seapage water from the Sweet Water Canal generally was sufficiently clear to allow of the breeding of anopheline mosquitoes, and it could be readily used for human consumption without further purification other than chlorination. It was a general agreement that if a water with a clarity of one metre was supplied by the R.E. from any source it could, by reasonable chlorination, be rendered fit for consumption.

The Suez Canal defence line with its elaborate water supply system ceased to serve any useful purpose after El Arish was occupied in December 1916.

The Advance to El Arish.

By the end of June 1916 the Suez Canal defence scheme was practically completed. In front of the army stretched

the almost waterless country known as the Sinai Peninsula. To cross this into Palestine there was only one practicable route. It started at Kantara, traversed some 25 miles of sandy desert, then, passing through the Katia oasis, ran along the northern edge of a belt of sand dunes, extending from Sabkhet el Bardauil on the north, to the Gabel el Maghara on the south, and reached the sea coast near El Arish. In the sand dunes, water could almost always be found by digging in the sand nearly to sea-level. This water was almost always brackish, but some of it was quite drinkable. The sand dunes collect the rainfall and retain water in their lower sand beds which rest on the top of a salt saturated bed covered with a thin layer of impervious clay.

Between Bir el Abd, the eastern limit of the Katia oasis, and El Arish local supplies were scanty, but in the valley of the Wadi Arish there were unlimited supplies of water available. It was decided that the best way to carry the water from Kantara to El Arish, a distance of 96 miles, was by a pipe-line in four sections, as already described.

Arrangements were also made to develop the local water supplies during the march across the desert. Every field company of the Royal Engineers was organized to provide twelve "well units." Each of these units carried lift and force pumps, Norton's tubes, water troughs, and a canvas tank to store water, also tools to dig shallow wells and material with which to line them. An officer of the Royal Army Medical Corps was attached to each company of the Royal Engineers to test the quality and salinity of the water obtained. A few ancient wells lined with stone or brick were found along the caravan route and provided small quantities of good water. Bedouin wells, circular in form, 15 to 20 ft. deep, with a diameter of 3 to 5 ft., and lined with twigs in the form of basket work, were found dotted over all Northern Sinai. The Turks in their advance to the Suez Canal had made a considerable number of wells, but nearly all these had been lined with wattle revetment made from roots of desert plants, or with split palm tree logs, and the water had become so tainted as to be unfit for use. The Royal Engineer companies found that the best water was generally near the sea and where there was least vegetation. No drinkable water was found near palm groves, the juices from the roots of the trees rendering it unpalatable, and where much scrub grew on the dunes very saline water was present. Large numbers of wells were dug in depressions where the water was known to have a low sodium

chloride content. With subsequent pumping the figures rose to what might be thought an unsafe amount. Troops quartered in the neighbourhood drank the water without any apparent ill-effects. Bodies of mounted men were observed drinking water with a salinity of 200 to 300 parts per 100,000 for a week to ten days with no symptoms. Much depended on the proportion of the salts present. In some localities these waters produced diarrhœa, in others the chief symptoms were dyspepsia and constipation, due presumably to the presence of salts of calcium. Palatable infusions of tea could not be made with these waters, and vegetables boiled in them became extremely hard. Experiments showed that tea was palatable when the chlorides did not exceed 120 parts per 100,000, and medical officers came to the conclusion that 150 parts of sodium chloride per 100,000 was the limit which should not be exceeded in drinking water to be used by the troops; for general use 100 parts per 100,000 was a safe guide. Horses readily drank water with 500 parts, and camels water with 1,000 parts per 100,000. It was noted that both men and animals gradually came to prefer slightly brackish water to that of the Suez Canal supply, and difficulty was experienced in getting horses to drink the latter when they returned to the Canal area to rest. The preference of troops for tea made with slightly brackish water is reminiscent of the old Scottish custom of putting a pinch of salt in the teapot with the tea.

The wells dug by the R.E. companies were 6 to 8 ft. square, and lined with corrugated iron on a wooden frame. The Field Squadron, Anzac Mounted Division, had what were locally known as "spear points," a useful local variation of the Norton tube well, made of 2½-in. steel tubes, cut in 5-ft. lengths. The lowest length was fitted with a solid steel spear point, to enable it to penetrate the sand, and was perforated, the perforated portion being covered with fine gauze or wire cloth to exclude sand. The extension lengths were plain tubing with screwed collars, and a special coupling was provided to enable the suction length of the service lift and force pump to be connected to the tube well. Under favourable conditions a spear tube well could be driven in a few minutes, and would produce up to 600 gallons per hour. Spear points were also used to improve the yield of old wells which had silted up or become choked with mud.

Fig. 7 shows a spear point well; the water was stored in canvas tanks which were supported by a wall of sandbags and

supplied fantasses of the camel convoys. The *shadoof,* an Egyptian device for raising water from wells, was also employed.

Fig. 7.—Sketch of spear point well.

During the advance from Romani to El Arish, the troops subsisted on scanty local supplies and on filtered water brought up by rail from the nearest source of supply, at first from Kantara, then from Romani, and afterwards from Bir el Abd. Fig. 8 shows the method of distribution.

At Kantara, and subsequently at Romani and other watering stations as they came into use, special water sidings were laid alongside the railway, and here twenty or more stand-pipes were erected, so that a whole train of tank trucks could be filled without shunting (Fig. 9).

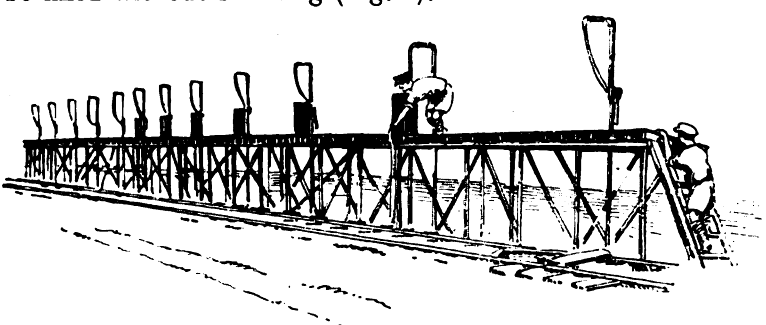

Fig. 9.—Stand-pipes for filling tank trucks.

At railhead, canvas storage tanks were provided at a special water siding ; the tanks could be quickly filled direct from the water train, which on the average had 20 trucks holding 2,000 gallons of water (Fig. 10).

The pipe-line into El Arish was completed on 5th February, 1917, and after that time was worked without intermission ;

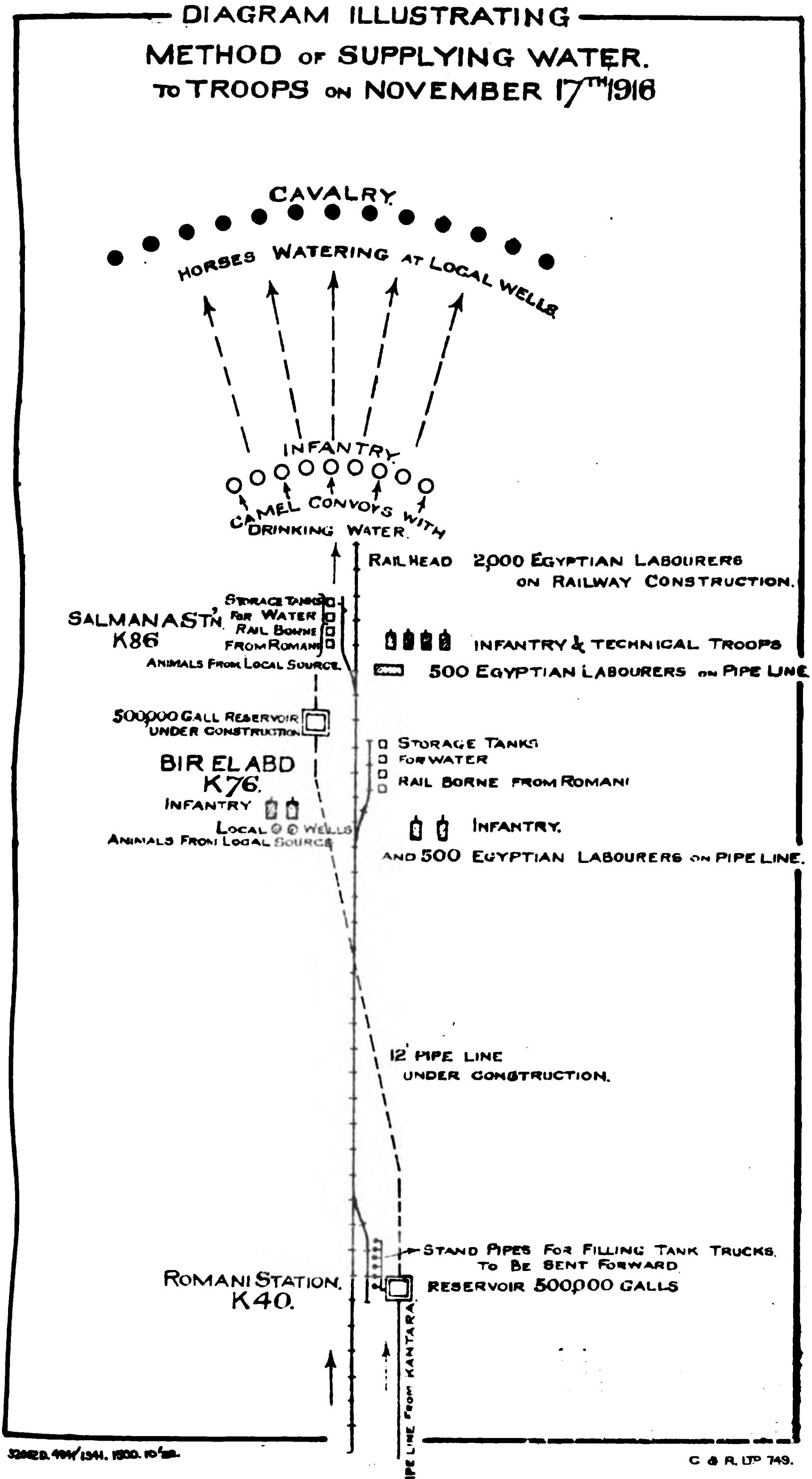

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FIG. 8.

it was subsequently extended to beyond the Wadi el Ghuzzee, in Palestine, where its branches supplied filtered Nile water to the troops during the operations which drove the enemy from his position round Beersheba and Gaza.

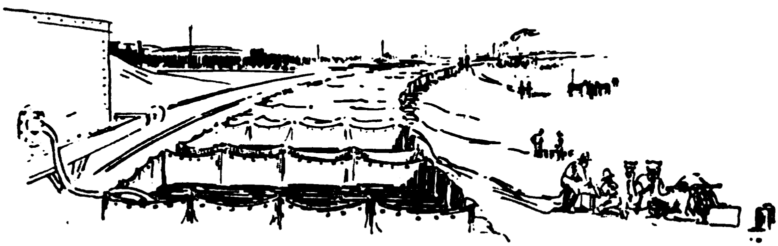


Fig. 10.—Canvas storage tanks.

El Arish to Beersheba and Gaza.

When El Arish was reached there was for a time no great difficulty in supplying the army with water. In the valley of the Wadi there were some wells of fairly good water, and the sand dunes right down to the edge of the sea, and especially on the sea beach, produced good supplies. Dr. Hume, geologist to the Egyptian Government, suggested that the Wadi bed should be reserved for animals, the area between the town and the sea for the supply of locomotives (if the hardness permitted), and that drinking water should be drawn, as far as possible, from the areas to the west of a line drawn from the western extremity of the town to the sea. The liability to contamination was most marked in wells situated between the town and the sea. To meet railway requirements and to provide additional supplies for the troops, the main piped water supply was extended into El Arish, and a storage reservoir of 250,000 gallons capacity was built.

The forward road followed the general line of the coast, and was separated from the sea by a belt of sand dunes from one to three miles wide. Water was available in the sand dunes and the left wing of the Egyptian Expeditionary Force depended for its supplies on the water contained in the dune area of the Mediterranean sea border. The wells in the villages of El Burj, Sheikh Lowaid and Rafa were small and their yield scanty. At Khan Yunis a local supply adequate to the needs of the army was found; the yield from three wells there eventually reached 130,000 gallons a day. A few miles farther on, at Deir el Belah, there were numerous wells, and the water supply was practically unlimited.

The railway was pushed forward to Rafa, and subsequently to Deir el Belah, Shellal and Gamli. This was followed by an extension of the Kantara pipe line to Rafa. The Turkish position at Gaza was attacked by a force assembled at Deir el Belah, and storage tanks to receive water brought by rail from El Arish were erected at the railhead there. Between this railhead and the place selected for water distribution in the Wadi el Ghuzzee, pipes had to be laid over a ridge to the storage tanks. Pipe lines were also laid from Rafa, through Abu Khatli to Shellal and from Khan Yunis through Abu Setta to Abu Khatli, with a branch from Abu Setta to Abu Bakra. Until September 1917, when local supplies had been developed to the fullest extent, the troops continued to be supplied with water brought by rail from El Arish. About 100,000 gallons could be delivered at Shellal. The El Arish-Rafa pipe-line could supply 156,000 gallons a day to Rafa, whence 60,000 gallons a day could be delivered to Shellal or Abu Setta. The Khan Yunis well and pumping station could supply 100,000 gallons a day to Abu Skitta, and thence by cross line to Abu Khatli and Shellal. This total daily supply of 260,000 gallons was controlled by G.H.Q., and deliveries at the various watering points were regulated according to the daily movement of the troops.

The adequate development of the water supply for the Gamli-Shellal-Hiseia area, from which three mounted and four infantry divisions attacked the Turkish position, was of great importance. At Shellal springs supplied about 14,000 gallons per hour to a water-distributing area. A natural rock basin provided storage for 500,000 gallons of water, which could be pumped forward to Karm. A fantasse-filling area, in which 2,000 fantasses could be filled and loaded on camels, was organized. At both Gamli and Hiseia water was pumped to high level storage tanks, which supplied water by gravity to fantasse-filling areas.

On 22nd October, 1917, troops began to move eastward to take up their position for the attack on Beersheba. The Desert Mounted Corps obtained water from two wells sunk in the Wadi bed near Abu Ghalyun, from trenches dug in the Wadi bed at Malaga, from two wells at Khalassa, and from wells at Asluj. The water supply of the 20th Corps was derived from springs and pools in the Wadi bed at Esani, from storage tanks erected at Imara and filled with water pumped from Shellal. Subsequently, water was pumped through Imara to Karm, where eventually 80,000 gallons a day were delivered

by rail from El Arish. Besides these supplies cisterns at Khasif were cleaned out and filled with 60,000 gallons of water brought up by two camel convoys, and thus provided an additional advanced reserve of water.

In the operations against Beersheba, 33 pumps were erected and the water storage capacity in tanks and reservoirs amounted to 1,100,000 gallons.

After the capture of Beersheba only two out of the seventeen local wells were found to have been destroyed, and two partly damaged. The Turks also left intact two reservoirs containing some 90,000 gallons of water. The wells were repaired as far as possible, and pumps were erected ; on the fourth day of occupation the total output was 390,000 gallons a day. After this there was no further anxiety in regard to sufficiency of water.

From the Beersheba–Gaza Line to the Wadi Auja (Jordan Valley)–Tel Usur–Arsuft Line.

The country occupied between November 1917 and September 1918 stretched from the Dead Sea and the Jordan Valley on the east, to the Mediterranean on the west. The geological conditions affecting the water supply were the Judean hills, formed of irregularly stratified and much fissured limestone rocks of various ages, resting on the Nubian sandstone beds ; between the Judean hills and the sea an undulating plain of loam and sand, and along the edge of the sea a low ridge of sand dunes.

In the whole of this area there was very little water to be found above ground. In the hill country a few streams were found in deep gorges flowing into the Jordan and the Dead Sea valley, but these were very inaccessible except in the Jordan valley itself. On the western side of the hills water ran for a short distance along the bed of a few deep valleys. Close to the sea coast water was found in the sand dune area in the bed of the Kahr Sukerier and the Kahr Rubin. In the hill country springs were found at various altitudes. The population in this part of the country was supplied from these springs and also very largely from cisterns in which the water was collected during the rainy season. In the plains there were no springs, and the people obtained water from deep wells dug into water-bearing sands through some hundred feet of sand and loam, and sometimes through calcareous sandstone of recent date.

From the information obtained it was evident that for the operations in Palestine the troops would have to rely largely on power-driven pumps for deep wells. The Royal Engineers' Headquarters of each division had a special park of engines, pumps and water gear, including two deep well pumps carried on four trestle waggons. Detachments of the field units were also practised in the use of *chursas*, an Indian device for raising water from wells; a large number of *chursas* of various patterns was made and issued for the advance (Fig. 11). A special Royal Engineer Water Supply Company was formed to follow the advance and to establish and maintain water supplies in rear of the army and to take over installations left by corps as they advanced.

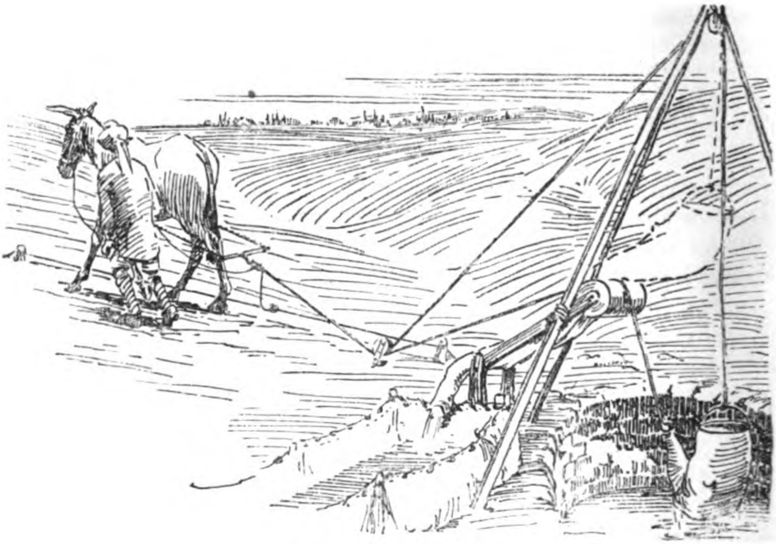


Fig. 11.—A *chursa*.

After the capture of the Beersheba-Gaza positions the mounted troops advanced on the right through foot-hills where water was scarce, and the infantry along the coastal plains. *Chursas* were freely used, also lift and force pumps, but for some days many horses went short of water. When the mounted troops reached the plains south of Ramleh and Jaffa they found many power pumping plants installed in deep wells in the Jewish agricultural colonies; these plants were rapidly repaired and by these means and by the use of *chursas* sufficient water was obtained. In Gaza most of the wells were found

intact, but the engines and water-raising plant had been damaged. Here the light deep well power plants of the divisional Royal Engineers came into use at once. On the coast in the sand dunes " spear point " tube wells were used, and in the villages further inland *chursas* were employed and power plants erected. When the army arrived in the plains about Ramleh a considerable number of good wells with power pumps was found in orange groves and gardens. The newly formed Royal Engineer Water Supply Company followed the advance and improved the water supplies along the lines of communication.

Many of the wells in Palestine were more than 100 ft. deep and though they provided sufficient water for the needs of the inhabitants could not yield enough for large bodies of troops, as in many cases thay had been sunk for a very short distance into the water-bearing sands. In nearly every case they were also more or less choked with mud, stones and old water vessels. It was often difficult to decide whether to attempt to improve the yield of a well by cleaning it out or to leave it alone. Cleaning operations occupied a long time, but were often successfully carried out by the Army Troops Company following the advanced troops. In most of the agricultural colonies the yield of ordinary stone-lined wells had been improved by sinking perforated tubes covered with wire gauze and screens for 20 to 30 ft. below the original bottom of the well. It was not uncommon to find wells of this kind yielding 6,000 gallons per hour. In some cases more powerful engines were erected by the Royal Engineers so as to obtain a greater output, with the result that the sand screens broke down and the wells became choked with sand. The boring detachments sank numerous wells during the advance and often experienced a similar difficulty in screening off the sand. No tube well sunk into the limestone hills or into limestone strata yielded a satisfactory supply of water.

When the army reached Jerusalem in January 1918, the sources of water supply were several, namely, rain-water collected from the roofs and yards and stored in underground reservoirs; rain-water surface drainage of the upper part of the town, quite unfit for consumption, which was collected in the ancient reservoirs, the Birket Sultan and the Birket Mamilla; water collected and pumped from springs near the Pools of Solomon and brought into the town by an ancient badly maintained aqueduct, with an output of 40,000 gallons a day, and the springs of the Pool of Siloam which lay below the town and were polluted by sewage. These supplies in normal times were

barely sufficient for the needs of the civil population and use was made of the springs in Wadi Arrub, which in 1908 M. Franghia, a French engineer, had calculated would yield 380,000 gallons a day. A delivery of 300,000 gallons a day was obtained until October, when the upper springs failed and the yield of the lower was only 150,000 gallons a day. Fortunately the full supply was not then required, as nearly all the troops had left Jerusalem and the principal cisterns in the town had been cleaned out and refilled.

When the Jordan valley was occupied and operations beyond the river were undertaken it was found necessary to establish a water point on the road from Jerusalem to Jericho. At this point 40,000 gallons of water were pumped daily from the Wadi Kelt up to the road. In the hills north of Jerusalem during the summer months a number of pumping stations and pipe-lines had to be provided to bring water from the deep valleys to the troops. In the plains, also, the development of water supplies went on continuously to meet local requirements and in preparation for the concentration of troops before the final advance in September 1918. Previous to the advance a pumping station was erected on the River Auja and 800 yards of pipe-line were laid reaching just beyond the first line of trenches. The work was done at night and carefully concealed during the day. On the day of the advance the pipe-line was extended to a distance of 5,000 yards and storage for 60,000 gallons erected there. After the advance the Royal Engineer Field and Army Troops Companies were able to cope with the requirements of the formations to which they belonged and the special Water Company sent forward detachments to restore and develop wells as a supply for the railways.

From the above account of the works carried out to provide water to the troops in Egypt and Palestine it will be seen that in Egypt and on the Suez Canal extensive engineering works were necessary, the water being sedimented, filtered, then chlorinated and distributed in pipes to the various posts. It was necessary to ensure that the water was sufficiently chlorinated to destroy all germs of water-borne disease, and further, that the treatment as a whole was such as to prevent the carriage of bilharzia disease to the troops.

Dr. Leiper's work in Egypt showed that chlorination as ordinarily practised for drinking water did not suffice to destroy the cercariæ, which might even pass through the filters. Storage for forty-eight or even thirty-six hours was an effective protection, and every attempt was made to secure

adequate storage, but owing to military exigencies this was not always possible. Major Searle, R.A.M.C., reported 22 cases of bilharzia in the 1/4th Northampton Regiment at El Kubri; 19 of these were infected by bathing in the Sweet Water Canal, which was known to be infested with *B. contortus* snails, the host of the vesical form of bilharziasis. The remaining three cases were infected by washing in a cattle trough at El Kubri, the water of which was drawn from the Sweet Water Canal by pipes, which passed beneath the Suez Canal to the Sinai bank. The water had not been filtered, but was pumped into canvas troughs and labelled "not drinking water." Major Searle stated that the infection was certainly introduced through the skin and not by drinking water.

After the battle of Bold Hill on 24th December, 1917, the East Anglian Division occupied Mulebbis, a Jewish colony north-east of Jaffa. On 10th February, 1918, in connection with a strenuous anti-mosquito campaign, Major Searle was inspecting water supplies in an orange grove a mile south-west of Mulebbis and found a number of *B. contortus* snails crawling over the bottom and sides of a cistern. The snails were identified by Major Austen of the British Museum, South Kensington. Between February and August 1918 hundreds of cisterns, wells, swamps and mosquito breeding places, including the River Auja, were examined, but *B. contortus* was found only in three of the open cisterns near Mulebbis, in one deep well adjacent to a cistern, and in a pool near the village of Kafrana. Major Austen found *B. contortus* in Burak Leil only, a pool near El Jelil, subsequently obliterated in the course of anti-mosquito operations by the 21st Corps. Three cases of bilharziasis were traced to the cistern in the orange grove, and one to another cistern half a mile north of Mulebbis, which also contained Bullinus snails. The cisterns were treated with cresol and then emptied; a guard was placed over them and the troops were not allowed to make use of the water.

The supervision of the purity and the control of the chlorination of water from all the filtration plants on the Maritime Canal, and of the filtered water delivered from the filtration plant by the pipe lines running eastward from Kantara, were undertaken by No. 30 Sanitary Section, whose headquarters were at Kantara. Two men of the section were placed at each filtration plant and at chlorination and other stations, where necessary, on the 12-in. pipe. They were responsible for testing the purity of the water and for estimating the quantity of bleaching powder to be added; they had to supply the officer

commanding the sanitary section with daily reports on the results obtained and observations on the working of the filtration plants. The officer commanding was also instructed to take weekly samples from all filtration plants, pipe-lines and reservoirs, and submit them for bacteriological examination to the nearest field laboratory, and he had to keep in constant touch with the special Royal Engineer officers in charge of filtration plants and pipe-lines. He was also responsible that an adequate supply of bleaching powder for sterilization of the water was maintained at each post, where also a water sterilization test case was provided for the use of the men in charge. Samples of the chloride of lime were sent frequently to the field laboratories so that the available chlorine might be estimated.

All water trucks, iron tanks and canvas reservoirs into which water from the pipe line was delivered were periodically cleansed by fatigue parties under the supervision of the personnel of the sanitary section.

Efficient purification of the water supplies was rendered difficult owing to the variable and at times very poor quality of the bleaching powder received. Of 56 samples examined at the central laboratory in Cairo, 1 sample contained over 30 per cent., 19 samples between 20 and 30 per cent., 25 samples between 10 and 20 per cent., and 11 samples between 1 and 10 per cent. of available chlorine. The supplies of bleaching powder were received packed in 4-oz. round tins and in 60-lb. drums. The tins were often rusty, and even eaten through; the drums were more satisfactory. Samples received in 1917 were packed in 4-oz. tins, 4-oz. jars, and 20-lb. jars; the average of available chlorine being 24·8 per cent. in the tins, 24·25 per cent. in the 4-oz. jars, and 27·7 per cent. in the 20-lb. jars.

After the forward movement of the troops from the canal the troops depended on the pipe-line carried forward from Kantara and on the development of local wells. Instructions as to the disinfection of wells were issued, and regimental medical officers were made responsible for the disinfection of the wells in the area occupied by their units, and for the satisfactory chlorination of the water supplied to the troops, and were provided with water sterilization test cases. The water-duty men of the unit were each supplied with an equipment consisting of one ½-pint tin or mug, four ¼-lb. tins of bleaching powder, a box containing an oil can or bottle filled with test solution of zinc iodide and starch, an egg cup or small

white pot, a reel of five yards of stout string attached to a ½-lb. weight, a packet of waxed confetti, Army Book 153 and pencil, and a stick 3 ft. long. Each man was allotted the duty of treating all wells in the strip of the country over which the part of unit to which he was attached advanced. He had to maintain touch with the men allotted similar duties on his right and left, so that wells on the margins of adjoining strips of ground should not be overlooked, and to note in the Army Book the positions of all wells treated. At the end of each day's march he handed the list of treated wells to the medical officer of the unit. The following instructions were given to the water-duty men of the unit for treating the wells :—

"(1) Test the freedom of the test solution and egg-cup from chlorine, by dipping up some of the well water in the egg-cup and then adding a few drops of the test solution. If a blue colour results the cup must be washed out repeatedly until the water remains colourless on the addition of the test solution.

(2) The bleaching powder is measured in the tin measure attached to the lid of the ½-lb. tin of bleaching powder. The amount depends on the size of the well and the condition of the water; the following are rough guides :—

Wells	6 ft. square	by 2 ft.	deep	60 measures.
,,	4 ft. ,,	,, 2 ft.	,,	30 measures.
,,	2½ft. ,,	,, 1½ft.	,,	15 measures.

Commence therefore by adding 15 measures of bleaching powder, which should be mixed in the mug with just sufficient water to make a thin cream, and then wash out into the well. The contents of the well must be thoroughly churned up.

(3) Dip up a sample of the well water, free from floating particles of bleaching powder and add a few drops of the test solution; if a blue colour results, wait for five minutes then test a fresh sample of the well water. If a blue colour still appears the well has been fully disinfected.

(4) If no blue colour results add a further 15 measures and test in a similar way.

(5) When the well has been disinfected throw into it a measure or two of confetti which will float and show later comers that the well has been treated."

When a well was not disinfected and the water was used only for ablution purposes, cresol was added to the water so as to render it undrinkable.

Water-carts and fantasses had to be periodically cleansed with a strong solution of bleaching powder, and particularly before the commencement of any active operations.

Many of the wells in Palestine were found to be infested with leeches, which had to be destroyed. Chlorination as ordinarily performed did not destroy them, but it was the practice in one corps, after the water had been chlorinated, to direct the contents of one chlorine gas cylinder into the "lead" of the well, the mouth of which was kept hermetically sealed for one week. At the end of this time when the gas had been pumped out, no leeches were found in the well, and when it was re-examined a month later they were still absent.

CHAPTER VI.

CHARACTER OF THE WATER IN NORTH SINAI.

THE investigations into the water supply for the advance of the British troops from Egypt to Palestine were connected with three phases of the operations; namely, the defence of the Suez Canal, the development of the advance through North Sinai, and the concentration of large bodies of troops at El Arish and west of Gaza.

Defence of the Suez Canal.

The problem of water supply during the defence of the Suez Canal was simplified by the presence of the Sweet Water Canal, but it was found necessary to study the question of additional supplies for the large camps organized in rear of the main defensive lines, such as at Tel-el-Kebir. Based on previous knowledge of the underground water supply in the Delta, a boring was sunk near Tel-el-Kebir station to a depth of 51 metres and potable water obtained.

There was also successful shallow boring in the dune region near Ismailia and to the west of Serapeum, in both cases the presence of good water being due to infiltration from the Sweet Water Canal.

The details of the strata passed through at Tel-el-Kebir were as follows :—

Metres.	
0 – 2	Nile mud.
2 – 22	Very fine clear quartz sand; majority of grains not exceeding ½ mm. diameter. Grains mainly water-clear and sub-angular to rounded.
22 – 23	Compact reddish-brown clay. Before this clay was pierced, water stood at 3–4 metres below ground level. Immediately clay was passed through it rose 2½ metres, almost to ground level. Water reported sweet to the taste.
23 – 31·6	A coarser sand; grains still largely water-clear, sub-angular to rounded. Quartz ½–1 mm. diameter. Individual opaque pieces over 5 mm. diameter.

Metres.	
31·6– 50	Coarse sand, coloured yellow by iron oxide. Finer material ½ to over 1 mm. in diameter. One opaque quartz-pebble 1½ cm. in diameter, others nearly ½ cm.
50 – 51	Coarse sand. Grains of 1 mm. very common. Individual grains up to 3·5 mm. diameter. Large number stained yellow or red by iron oxide.

The scheme for the advance through North Sinai involved a study of the water supply for the outposts in the desert east of the canal, and of the water supply for the gradual advance towards Palestine.

All previous indications were unfavourable to the obtaining of good supplies east of the canal, it being known from experience in the Delta that no good water had been tapped beneath the soils containing the brackish water cockle (*Cardium edule*). The presence of this cockle in the material dredged from the canal indicated a wide extension of these lake-beds and consequent unfavourable conditions.

Nevertheless, the matter was of such importance that late in 1915 the military authorities decided to make an examination of the canal area, notably at Kantara, Ferry Post, Toussoum and Serapeum.

It was decided to test this area by boring, in order to see whether the sands became coarser and contained better water derived from the higher Sinai area to the south-east. Emphasis was also laid on the importance of sand dunes as holders of water.

Borings were undertaken at Kantara, Ferry Post, Serapeum and El Shatt, the details being as follows :—

Place of boring.	Depth of bore in feet.	Nature of strata.	Character of water.	Remarks.
Kantara ..	200	Sands under 35ft. of clay	Very bad; 50,670 parts salt per 1,000,000.	Water apparently rises near to surface and is abundant.
Ferry Post, Ismailia	150	Sandy clay. Sand and clay alternating for last 52 ft. from 98 ft.	Very bad; 30,690 parts salt per 1,000,000.	Ditto.

Place of boring.	Depth of bore in feet.	Nature of strata.	Character of water.	Remarks.
Serapeum ..	150	Practically all sand. No clay. Hard beds in series of sand cemented by limestone.	Water scarce, deep down and salty.	
El Shatt ..	75	Reached hard limestone. Gypsum crystals noted from 50 ft. to 55 ft.	Water only near surface. Poor.	

In consequence of these results it was evident that efforts to obtain good water along the canal itself would be failures in all cases.

It was consequently advisable to test the water in the sand dune areas where military posts were to be established some distance east of the canal. The spot selected for the first test was at Bir Abu el Aruq, some seven kilometres north-east of Ferdan, a station on the Ismailia-Port Said Railway. The main country east of the canal is slightly undulating, with masses of highly-rounded sand of fairly coarse grain. Through it rise more solid portions covered with scattered limestone fragments. This appeared to indicate the presence of a thin limestone band forming the basis of the country, and covered with a light pall of sand dunes.

This limestone layer being identical in appearance with one forming the plateau behind Ferry Post, and in the cliff at Serapeum, it was concluded that the indications pointed to the presence of a series of sands with possible occasional clays underneath the whole area.

Abu el Aruq is in reality a small oasis, containing several groups of palms, about 200 in all, together with numerous tamarisk and other bushes. The salty bowal (a *Zygophyllum*) was scattered all over the district in drainage hollows and shallow valleys. A test bore was recommended here for several reasons. There was strong evidence for believing that there were thick bands of sand beneath the oasis level. The oasis was in a drainage-line immediately descending from a sand-dune covered area. As sand dunes tend to hold up rain-water, there was a possibility of percolation of water into the highly porous strata below, and such ground water, if

retained by a suitable stratum, would be tapped by the borings. Such water, being fresh, might tend to replace the salt water if the dip slope of the beds was toward the canal.

It was considered, in fact, that this locality would give the best possible tests for the water capacity of the underlying sands, just as the tests previously carried out in these porous strata at Ferry Post and Serapeum were under the worst possible conditions, namely, in close proximity to the canal.

The results proved as expected. Sands were present down to a depth of 165 ft. at the northern end of the palm grove, when a limestone band was met with. After pumping for fifty-two hours the salt content in the water was 5,086 parts per million.

The trials recommended under the great Sand Dune of Kitab el Aruq struck water at a lesser depth (40 ft. and 55 ft. respectively), and the final results for the latter were :—

Before pumping ..	2,555 salt content parts per million.
After 40 hours' pumping	2,619 salt content parts per million.

Sulphates were 333·4 and 348 parts respectively.

At the time it was considered that this water was just on the limit permissible for horses, and could certainly be used by camels accustomed to the desert, while there was a suggestion of improvement as one advanced eastward and upward from the canal.

This type of research was continued all along the eastern side of the Suez Canal at some few kilometres inland.

In June 1916 it was possible to bring together the chief results up to that date.

The most noticeable feature was the discovery of a water-table of wide extent at, or near, sea-level. Bir Mahadat, Bir el Dueidar, Bir Romani and Bir Abu Aruq were all in depressions below the 15 ft. contour. This water table, where it reached the sea border, was indicated either by marsh, gypsum swamp, or palm-grove depressions. It was thus broadly concluded that along the Mediterranean border water could be met anywhere at sea-level. Thus, where the height was 100 ft. above sea-level, the depth of the well required would be about 100 ft.

The quality of the water varied with the season, the time of year, and the position of the well as regards protection from sunlight. Analyses were carried on by the hygienic laboratory

at Cairo of samples from selected wells in order to study the question as fully as possible. The conclusions indicated that, speaking generally, the water was either unfit for human consumption or only just potable. Thus, two wells at Bir Mahadat gave 2,145 and 4,852 parts salt per million respectively. Other results were :—

	Bir el Nuss	5,616 parts salt per million.
	Bir el Dueidar ..	8,125 parts salt per million.
Special borings	Bir Abu el Aruq ..	5,086 parts salt per million.
„ „	Kitab el Aruq ..	2,555 parts salt per million.

The quantity of water was small at any one spot. It was soon evident, and further confirmed by a boring made at Mahemdia, on the coast some 40 kilometres south-east of Port Said, that anywhere adjoining the Mediterranean coast in this region or the Suez Canal, the deeper-seated water was absolute brine, but that, on the other hand, in the dune areas, which now formed the military front at Romani, comparatively fresh water could be collected from the dunes resting on a more saline layer at sea-level (Fig. 1). The strata, at

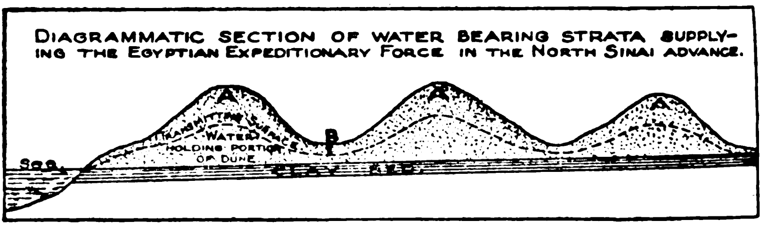


Fig. 1.

sea-level, were of a more clayey nature, probably due to deposition of clayey matter in contact with infiltrating sea-water. The general conclusions of the water survey party were that no water found was fit for human use, but in many cases could be used for camels and even horses ; that in general the freshest water was found near the surface, and that the water became worse in its quality in proportion to its distance from the surface.

It had become evident that if large masses of troops were to be gradually pushed forward over the desert, more dependable

water supplies would be needed. Consequently, it was decided to carry the water of the Nile by pipe-line along with the advancing troops.

As soon as it was proposed to bring the water from the Sweet Water Canal, the ground on lines to El Ferdan and Ballah was examined by pitting. On the El Ferdan line the first 5½ kilometres passed through a green, salty, quartz sand, the last 2½ kilometres partly through salty, green clay, and partly through dune sand. At Ballah, two materials were found to be forming the ground; the one an upper sand-dune series composed of quartz and crystalline gypsum sands, and the other the lagoon bed series, which forms a perfectly flat plain for at least 3 kilometres covered with cockle-shells, gypsum crystals, and solid granular gypsum, in places a metre thick, with underlying clay.

There was a good deal of divergence of opinion as to running the water in a channel through the gypsum, the manager of the local gypsum works not expecting serious difficulty, while the Suez Canal Company's engineer held the opposite view. Experiment settled the question conclusively, the granular gypsum proving very unsatisfactory in contact with water, while a salty marl forming part of the lake floor was still worse, the salt, in dissolving, breaking up the finely divided clay. Consequently, in leading the water from the Sweet Water Canal to where it crossed the Suez Canal, it was found advisable to carry the channel through the dune series as far as possible, and so reduce the heavy expense of pipes. Indeed, at that time, early in 1916, piping was difficult to obtain.

Both before and after the victory at Romani, the advance depended on the pushing forward of the Nile water pipe-line and on the presence of water in the Katia oasis and the sand dune areas east of it. Special attention was called to the distribution of the slightly brackish water wells in the Oghratina-El Arish area east of Katia in July 1916, and during late 1916 the area between Katia and El Arish separating the British from the enemy lines was being studied by patrols and survey parties with a view to the coming advance.

The occupation of El Arish in the closing days of 1916 led to a new water study by Dr. Hume. The question presented *itself* in three forms, namely, obtaining of water of low permanent hardness for locomotives, determining areas where water would be free from pollution, and the supplying of 300,000 gallons of water daily to meet the full requirements of the troops at El Arish.

The water supply round El Arish was exceptionally fresh when compared with water from the other localities between it and Kantara. It was apparently derived from the delta of the Wadi el Arish. The total area of the delta was about 18 square miles.

On the moist surface of this delta, differing little from sea level, the sands drifting from the west have anchored, leaving rolling dune country which, near the sea, is hollowed out into depressions, bordered by sand cliffs with a 30° slope on the eastern side. These sand-dunes, as already noted, serve throughout Egypt as holders of the rain water which falls on them, and as the fall is on the average 4 in. on the sea coast at El Arish, a large supply of fresh water is thus stored every year. The delta surface appears to be in the main a light yellow clay near sea level, and observation led to the conclusion that a definite water table, largely fresh, had collected on the clay at depths a little above sea-level.

A study was made successively of the quantity of water probably added yearly to the supply already available, its quality, both as regards salinity and hardness, the nature of the yield, and certain other questions as regards pollution, and possibilities of deeper boring.

The results of a calculation indicated that the area under consideration was approximately 9,292,800 square yards. If all rain were absorbed and made useful, the amount of water accumulated would be 1,037,600 cubic yards, a total of 174,519,878 gallons approximately. The amount needed for camp and railway necessities was reckoned at 300,000 gallons daily, or an annual total of 109,500,000 gallons. Experiments indicated that owing to evaporation, only about 25·30 per cent. of the whole water absorbed by the sand was available for the next season, the total effective addition being 43,629,969 gallons approximately. It was concluded from these figures that the amount annually gained by rainfall would thus be somewhat less than would supply 120,000 gallons daily—an amount sufficient to maintain two divisions, but leaving nothing available for railway supplies.

As the above amount represented a maximum, the extra quantity required had to be sought for by extending the area by boring beyond that of the Wadi el Arish delta to the district east of the Wadi el Arish, and to the bed of the valley itself.

The higher land which rises to the east of the Wadi el Arish forms a somewhat prominent scarp where it borders the valley. It is probably determined by the presence of a consolidated

sandy clay layer, similar to the one recognized on the west of the valley north and north-west of El Arish. It was found that near the seashore, as at El Risa palm grove, the water, though plentiful, was brackish, and consequently this region was only available for advance parties of Australian camelry or cavalry, the horses obtaining their water from the bed of the valley. In most of the Norton tube borings to the east the hard consolidated layer was met with at depths of 10–15 ft.

The valley of the Wadi el Arish proved a valuable additional factor in the water supply. Water was tapped by numerous wells, on the average 40 ft. deep, each yielding a supply of about 4,000–8,000 gallons in the twelve-hour day. There were also numerous wells used for horses and camels. Most of these were presumably shallow, fair quality water being present, but with no large individual supply.

The salinity* figures of the water holes in the valley, which were from 9–10 ft. deep, were 30–40 parts per 1,000,000. On 2nd February, 1917, a party returning from Bir Lahfan reported that Norton tube borings could not be undertaken in the valley bed there owing to a stratum of hard clay.

The question of amount and variation in salinity for each Norton tube or other well, as it was sunk by the Royal Engineers, was the subject of careful study by the R.A.M.C. staff. There was an active development of beach wells, the water close to the seashore having salinities which varied in the majority of cases from 292 to 1,316 parts per 1,000,000. Some were exceptionally saline. Thus, in two cases, it was pointed out that a branch of the sea ran up close to the wells, so that the current of salt water possibly drove back the fresh water supplies. In some wells it was found that there was rapidly increasing salinity, the probable explanation being that other wells had been sunk to the landward of them and cut off the fresh water stream. This blanketing of one well by another might, on the other hand, result in improvement to the inland well, the pressure of the opposing salt water supplies being reduced.

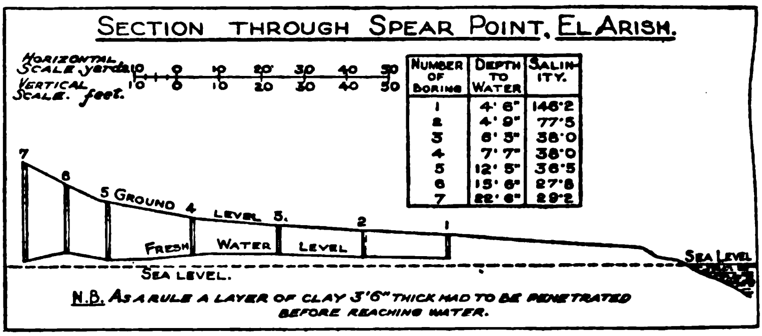
This led to the suggestion that it might be possible to keep shore supplies sweet by having a double line of wells, the inner for men, and the seaward for animals.

The principal wells in the Wadi el Arish valley had been wisely located near the foot of the high dune which borders its western side. They thus gained the advantage of obtaining

* Salinity indicates the sodium chloride content of the water, not the total soluble salts.

water from the fresh supplies sinking beneath the valley floor after rain, and also from those absorbed by the dunes. As a result, figures of from 380 to 468 salinity per 1,000,000 were recorded, and there seemed no reason why water of similar excellent quality should not be found along the whole of the western edge of the valley where it was dominated by the high dune. The difficulty of boring in the centre of the valley was its liability to run in spate at any period between October and June.

So far it was evident that the water supply of the El Arish area would not suffice to maintain the army which was now being concentrated at that spot. It was consequently necessary to consider the following points. With the Norton tubes available for boring operations, it was soon found that in the vast majority of cases the tubes reached a hard consolidated sandy clay, through which they could not be forced without damage. How serious was this obstacle may be judged from the fact that at one point only seven of forty-six efforts were successful in obtaining a water supply.



NUMBER OF BORING	DEPTH TO WATER	SALINITY.
1	4' 6"	146·2
2	4' 9"	77·5
3	6' 5"	38·0
4	7' 7"	38·0
5	12' 5"	36·5
6	15' 6"	27·8
7	22' 6"	29·2

Fig. 2.

Fortunately, the water in the high dunes to the west proved of better quality than those near the palm groves bordering El Arish. Thus, near the palm groves the water gave salinities between 80 and 117 per 100,000, while farther west they varied from 29 to 58 per 100,000, the water being at depths of from 10 to 24 ft. in this portion of the area. The relation of ground and sea-level to fresh water level is shown in Fig. 2. A study along this line showed a progressive diminution in salinity from the sea front inland, and indicated the relative horizontality of the fresh water level and especially its position above the sea-level, as also the fact that a layer of clay 3 ft. 6in. in thickness had to be penetrated before reaching water.

The final result of these investigations was to show that the best waters from the drinking point of view were those which were situated in the higher dune area west of the Wadi el Arish, bounded on the south-west by a line joining Masaid to Bir el Thamila, and thence to the town. From all observations made it seemed clear that the army had to depend on the fresh water supplies from above the clay, those below the clay, where tested, being distinctly brackish.

On this basis the plan for the position of camps, water for camps, water for railways and for horses and camels, was determined.

In order to determine the quality of waters as regards hardness, a series of water samples was sent to Dr. Todd, of the Hygienic Institute in Cairo, and the Egyptian State Railways also had analyses made for them by the Government Analytical Laboratory in Cairo. The permanent hardnesses varied from 10 per 100,000 at Bir el Thamila to 67 per 100,000 on the sea coast. The average of the first set was 28·7 per 100,000, that of the second 22, the waters thus being less hard in the main than those from wells in the chalk in England. In the western dune area the permanent hardness fell to 11 and 14 in the Abu Ebeid area.

It was concluded that the waters of low salinity would also be those of low hardness.

The yield of water in the El Arish area was a point of first importance. It was evident that very few individual wells yielded any large supply, and it was consequently necessary to sink as many wells as possible. The wells on the seashore yielded from 2,880 up to 10,560 gallons in twenty-four hours on the shore west of Wadi el Arish. The drinking water well in Wadi el Arish yielded a maximum of 8,000 gallons in twenty-four hours, while at Bir el Thamila two 6,000-gallon tanks could be filled every ten hours. Farther west there was a higher yield of from 6,984 up to 21,600 gallons in the twenty-four hours, thus again emphasizing the importance of the sand-dune region and the possibility of a freer flow of underground supplies in that direction. The best individual well was one already made before the British advance, the "Reservoir Well" of El Arish, which was said to yield 20,000 gallons easily, and showed no diminution in its supply when heavily drawn on.

These studies led to definite recommendations and it was decided that the water for camps should be selected from the dune area well to the west of El Arish, and that water for horses and camels should be selected from the area nearest the

Wadi el Arish, both on account of higher salinity of the water and the greater danger of pollution from the town.

As a result of the care and zeal displayed in connection with water supply large numbers of troops occupied the El Arish area for many months with a high standard of health.

During the French expedition, Reynier's far smaller army found itself in a difficult position owing to the exhaustion of the existing wells, and was totally unaware of the excellent supplies which lay close to the surface. The enemy seems to have been ignorant of the rich store of water available, and it stands to the credit of the Egyptian Expeditionary Force that it worked its advance on a basis of continuous study of the water supplies, with these striking results.

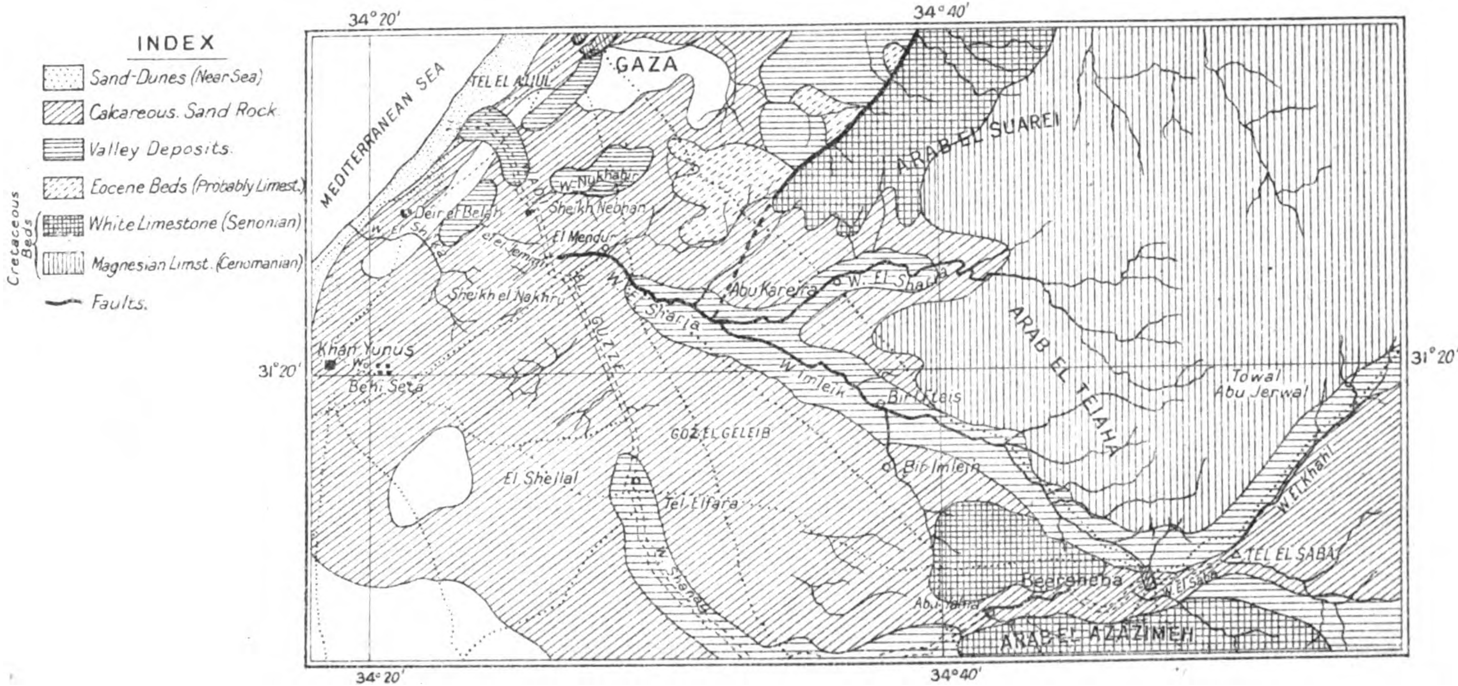


FIG. I.

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CHAPTER VII.

CHARACTER OF THE WATER ON THE WADI EL GHUZZEE NEAR GAZA.

OF the deepest interest to military students will be the study of how a great force was maintained before Gaza for many months, though based on its desert side and denied access to the more fertile plains of Palestine. The force which occupied the area was composed from January to May 1917 of approximately 105,234 men, 23,460 horses, 36,360 camels and 12,100 mules, and from June to November 1917 of 146,914 men, 34,760 horses, 36,360 camels, 18,150 mules and 8,000 donkeys.

The water supply for these large numbers was obviously of the first importance and was obtained in various ways according to the nature of the area occupied by the troops. Two sources of supply were available, the one connected with the belt of sand-dunes bordering the Mediterranean coast, and the other associated with the valley deposits found in the watercourses descending from the Judæan Hills.

From the data available, it was evident that the backbone of the country was formed by the limestone ranges of the Judæan Hills, which extend in a north-west and south-east direction, and rise to heights of over 2,000 ft. These limestone ranges send out spurs towards Bir el Essani and Goz el Geleib. The region was a highland, consisting of a marly white chalk alternating with regular flint bands, which had been deeply dissected by a number of valleys descending seaward in steep gradients. These hills or highlands had been eroded by two main valley systems, the Wadi el Ghuzzee, trending generally from south to north, and the Wadi el Sharia, trending from east to west and joining the Wadi el Ghuzzee 6½ miles from the sea. The Wadi el Ghuzzee was itself formed by the junction of the Wadis el Saba and Im'alaga, which combine to form the Wadi el Essani, the name given to the upper reaches of the Wadi el Ghuzzee.

The heavy erosion in the Judæan Hills resulted in the formation of valley deposits, composed of pebble gravels or shingle, clays and finer sands in alternating series. In a strong current large pebbles, sometimes several inches in diameter, composed of limestone and flint were carried along and deposited in the quieter reaches, while still further on, as the power of the current diminished, the sands and finally the clays were

deposited in their turn. These beds played an important part in the production of a water supply.

At Deir el Belah, near the sea border, there was a ridge composed of a mixture of strata of redeposited carbonate of lime or tufa, probably derived from solution of the inland limestones and true blown sand. The carbonate of lime deposits were well marked in the cliffs on the beach, and the blown sand on the shore line east of Wadi el Ghuzzee towards Gaza.

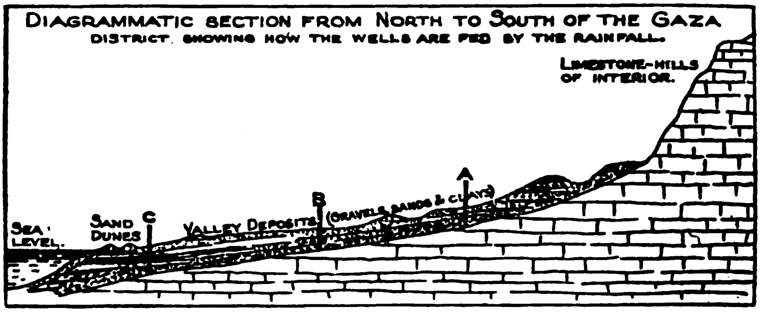


Fig. 2.

Farther to the south there was a second upland rise of very fine grained calcareous sand-rock and sand, probably also consolidated wind-borne material, which extended on the west side of the valley to Sheikh Nebhan and rose to an elevation of 200 ft. above sea-level. This sand-rock probably formed the soil-basis of the rises round Gaza and of a great part of the high ground west of Wadi el Ghuzzee. It formed an important part of the long slopes which rose towards the Azazma plateau, the steep red-brown cliffs of which formed the walls of the many small ravines which were being cut back by rain erosion into the upland of sand-rock.

On the ground of the slope or dip of the strata observed to the south at Bir el Essani, where the limestone dips north-east at about 4 degrees, it was thought that the Azazma plateau might be underlain by a mass of similar white limestone. If this were the case, then the limestone buttress had acted as an obstacle against which the wind-blown materials had been piled up and consolidated on the northern slopes, while the sand driven over it had been heaped up on the south-eastern and southern slopes, giving rise to the more normal sand-dunes accumulated in that region.

Consequently in studying the nature of the water supply, the parts played by sand dunes, valley deposits and limestone ridge had to be especially considered. At the same time the fact that the fine-grained consolidated dune material was also widely spread over the region occupied by the valley deposits was not overlooked.

The left wing of the Egyptian Expeditionary Force depended for its supplies on the water contained in the dune area of the Mediterranean Sea border. Here the conditions were not quite similar to those at El Arish. That is to say, the relation of the water-level to sea-level was somewhat different, the relation being

$$\frac{\text{height above sea-level of any point}}{\text{depth to water at that point}} = \text{unity} + 20 \text{ ft.}$$

or if the height of any point above sea-level is x feet, the best water supply would be found at or about $x - 20$ ft. below the surface at that point.

Again the best quality of water was found either in the shallow wells close to the sea or where the surface gradients were somewhat steep. Water tending to move parallel with the surface was descending under gravitation, and less liable to be charged with salts than if it remained stagnant and subject to evaporation.

All the wells met with between El Arish and Gaza, namely, El Burj, Sheikh Zowaid, Rafa, followed the rule of $\frac{\text{level}}{\text{depth}} = \text{unity}$, noted at El Arish. At Rafa the relation for one well was

$$\frac{\text{43 ft. above sea-level}}{\text{46 ft. depth to water}} \text{ and for the other, } \frac{\text{50 ft.}}{\text{48 ft.}}$$

both thus conforming to the rule. Bir Rufeih appeared from the figures to be exceptional, the relation being $\frac{\text{63 ft.}}{\text{36 ft.}}$

The water was in most instances of excellent quality, under 50 parts salt per 100,000, figures which would be accepted as good for any large city. From Rafa onward the relation that the level of the water in the well was met with at approximately 20 ft. above sea-level held good for wells at Khan Yunis (100 ft. deep) and Beni Sela (210 ft. deep) and also for the water table underlying Wadi el Ghuzzee, at Sheikh Nakhru and other places.

Generally the El Arish relation held good as far as Rafa, and probably also in the dunes which border the Mediterranean Sea.

Deir el Belah was an important headquarters and a number of wells were sunk there on the beach at the foot of a ridge which, ending in cliff faces towards the sea, rose to 88 ft. above sea-level. The quality of the water was in the main good, even in June, only containing as a rule from 30 to 40 parts of salt per 100,000.

For a time, considerable additions to the water supply were obtained from the collection of the winter stream waters in a depression at the lower reach of the Wadi es Selka, which extended between the sea border dunes and the slopes of the upland plain to the south. In winter and spring these waters formed a freshwater lake, at its maximum ¾ by ¼ mile in extent, additional water coming into it from the rainfall on the horse-shoe-shaped dune line lying to the north-east. Bordering this lake was a plain which rose to the 15-ft. contour. Water was obtained in it by digging to depths of from 10 to 25 ft.

The wells nearest the lake showed maximum salinity, the salinity also increasing with depth. Thus a series taken ran as follows :—

Depth.	*Salinity per* 100,000.
10 ft. 6 in.	.. 36
20 ft. ..	.. 78
63 ft. ..	.. 73
150 ft. ..	.. 250 rising to 1,000 on 29th June.

The wells as a whole yielded an average daily supply of from 8,000 to 12,000 gallons, having a salinity of from 23 to 72.

Eastward of Deir el Belah the dune waters retained their excellent quality and were easily reached. The headquarters were supplied by shallow sumps between Sheikh Rashid and Sheikh Shebasi, the depth depending on when the harder grey clay, a general feature, was met beneath the sands. At one place the salinity record was as low as 20 per 100,000. These extremely good results become more marked in the dune region on the east bank of Wadi el Ghuzzee. Thus at another place the salinity remained under 20 per 100,000 from the beginning of the occupation till June 1917 and elsewhere it varied from 40 to 69 per 100,000.

The influence of the dune waters was noticed still farther to the south where the saline content varied from 26 to 36 per 100,000.

The main points regarding the water supply from the dune areas near the sea may be summarized as follows. The advance of the army along the sea coast depended largely on the fact that water of fair potability was present wherever dune conditions

were developed within four miles of the coast. Unlike El Arish, where the water level corresponded closely with sea-level, the main water zone was from 15 to 30 ft. above sea-level, at Khan Yunis, Beni Sela, Sheikh el Nakhru, and in the Wadi el Ghuzzee between two and five miles from its mouth. The looser the texture of the sand-dune, the better was the quality of the water. Where the dune was close-bound, it contained much carbonate of lime which, entering into solution during rainfall, hardened the water.

Two sets of conditions adversely affected the quality of these dune waters. Near the mouths of the large valleys, where the sea is often driven up some distance in time of winter storm, water which normally had an average salinity of 40 might then have it increased to 200 or 300. Thus at Tel el Ajjul (the Caves) the salinities were from 140 to 302 per 100,000 and at another well, 82 to 102. The second adverse condition was that great variations were often found in shore wells in close proximity to one another. It seemed highly probable that this was due to the wearing away of the consolidated dune beds along part of the shore line, and the filling up of the spaces by the more loose-textured sea sands. In the latter the saline waters were able to mix with the fresh supplies, while in the dune beds proper the fresh water seemed to be less affected by this action.

As at El Arish, it was found inadvisable to have spear-points just behind one another in the main line of waterflow. In such cases those to seaward immediately became more saline.

Mendur or Wadi Es Sharia Drainage Area.

Leaving the dune area to the west of Gaza, the British front line extended along the high ground east of Wadi el Ghuzzee, crossing the head of Wadi Nukhabir, then passing east of El Mendur, and embracing the lower three kilometres of the Wadi es Sharia.

This area demanded very careful study from the point of view of water supply, as it was necessary to maintain a considerable force on this portion of the line. The important drainage line of the Wadi es Sharia was of special significance in this respect. In this area the valley deposits were first met with in important development to the east of Wadi el Ghuzzee. The area received the drainage from the permeable beds of the limestone ridge extending westward from Beersheba and also from the consolidated dune country towards Gaza. Both suggested that a fairly good quality of water

would be found collected in the shingle, but the first results from the Mendur boring, giving salinity figures of 6 and 12 per 100,000 were so startlingly good that they were regarded as exceptional. The old well at El Mendur had given a salinity of 134 per 100,000, which in itself was fairly good. This strengthened the opinion formed on other grounds that the best area for water development would be on the lower part of the northern slope bounding Wadi es Sharia on the north, where relatively shallow boring was expected to produce good results. The tests available at the time suggested quantities of 1,000 gallons an hour per bore. It was further considered that boring on the southern slopes might show more quantity and very fair quality; but as the water there was partly derived from the limestone it would probably be less good than that coming from the dune country north of El Mendur. Areas were selected for development, based on these considerations.

There was reason to believe that the Wadi el Ghuzzee influence prevailed as far as Sheikh Nebhan, perhaps acting like the sea in damming back the better Es Sharia waters. The salinities where Wadi el Nukhabir entered Wadi el Ghuzzee were found to have risen to 174 per 100,000, but immediately north of this valley the Wadi el Ghuzzee waters were of excellent quality, salinities as low as 26 per 100,000 being noted.

It was especially important to develop the water supply in Wadi el Nukhabir itself, and the development there had an encouraging outlook, as good water was expected to come from the consolidated dune area, which has steep slopes on both sides of the valley, while boring would be comparatively shallow. At one place a well gave about 600 gallons an hour, with a salinity of 116 per 100,000, and there seemed every reason for continuing active boring on both sides of the valley. An important boring was sunk at El Mendur, at a surface level of 130 ft., and to a depth of 84 ft., the water level being thus at 46 ft. above sea-level. The water was struck in a bed of sand, in which the individual grains were fine and of irregular shape. It was probably held up by a layer lower down in which the sand grains were cemented by a calcareous paste.

This well gave excellent results, having, like the one just referred to, a salinity of only 11·5 per 100,000. In the same way five wells sunk just below the confluence of Wadi es Sharia with Wadi el Ghuzzee, gave an average salinity of 18 per 100,000 in the month of July. All these results emphasized the importance of this portion of the Wadi es Sharia as a source of good water supply.

In Wadi el Ghuzzee, adjoining this section, there were wide variations. The area appeared to be a battle ground between the saline limestone waters and the fresh supplies from the dunes, local circumstances determining which should have the upper hand. It was expected that here, during the continuance of the summer, the fresh water supplies, if strongly drawn upon, would eventually give place to a more saline type, as the dune water was local, while the limestone waters came from widely extended districts.

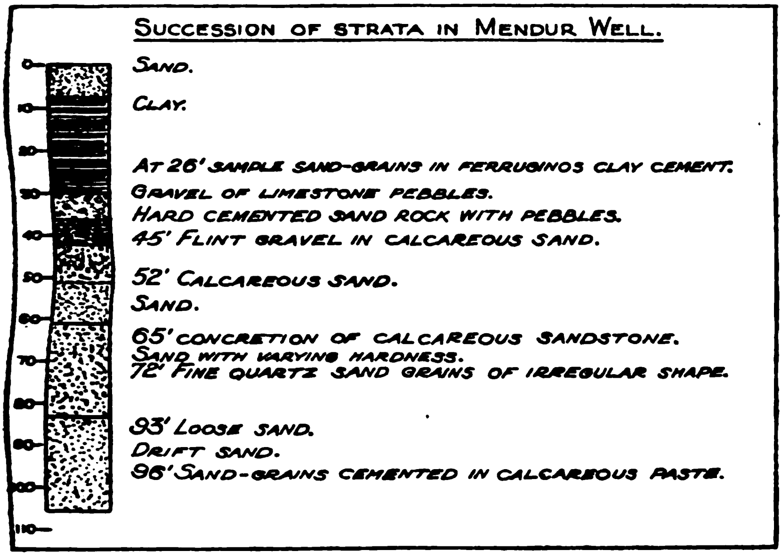


Fig. 3.

The line, however, was held intact throughout the difficult summer months, and this result was due to the regulated and controlled development of the water stored in the consolidated dune deposits bordering the Wadis Nukhabir and Es Sharia.

While the front line was thus obtaining good water in the consolidated dunes, it was necessary to ensure supplies for the troops camped on the heights dominating Wadi el Ghuzzee to the west. There was strong reason for believing that, though the consolidated dune material formed the surface of these highlands, they were in the main underlain by a core of limestone. If this were the case, it would not be surprising to find that the water of Sheikh el Nakhru, in the continuation of a valley system draining from the presumed limestone

ridge, should be a limestone water. There seemed no obvious reason why water should not be found in any part of the valley northward to Tel el Jemmi, the only reason for its non-appearance at the surface being that great masses of calcareous sand rocks, in which water will not remain, filled the valley. It was concluded that only testing would show whether this sand rock was underlain by the clay-shingle valley deposits which are described below. If so, it was expected that water from the limestone would be found there. Special places were recommended as being suitable for trial.

Until the Nile water was brought by pipe-line the most important supply on the west of the Wadi el Ghuzzee was obtained from the Sheikh el Nakhru well, an old construction of peculiar form, sunk in valley deposits. Just below it in a gully there was a very hard calcareous sand rock. It was difficult to judge of the rock succession of the well, because beneath the layer of hard rock there was a wall made of stone, succeeded by some more standing rock, and then again made stone.

Apparently where the water was present, it was associated with a light-tinted calcareous clay, while deeper down, at 143 ft., large blocks of flint were met with, obviously from pebble gravels of the valley deposit series.

The surface level of the well was 150 ft., so that the water stood at 23 ft. above sea-level. It thus seemed to belong to the same type of water supply as at Khan Yunis and Beni Sela. The water showed increasing salinity from 98 to 158–204 per 100,000, suggesting the influx of limestone waters as the supply was drawn on, and also a close resemblance to the water supply at Shellal, the special importance of which is noted below.

For the east of Wadi el Ghuzzee it was thought that the best water would be obtained by boring in or near the Sharia drainage, one spot being regarded as especially suitable. It was on the line of the Sharia valley and on a fairly steep slope, and received the waters draining from the Goz el Geleib; it was also in a good position to receive any supplies rising up from an important fracture line, believed, on the evidence available, to exist to the eastward.

Shellal Area.

One of the most interesting sections of the Wadi el Ghuzzee was the one which extends from El Gamli Pools through Tel el Fara to Es Shellal. In this section water was largely at

or near the surface, and the sides of the valley were markedly composed of an alternating series of valley pebble gravels and clays. Rain erosion had taken place in this region on a large scale, broken low hill scenery being produced on both sides of the main stream line. Here and there bolder outlines stood out, the most conspicuous being Tel el Fara, and farther north Tel el Jemmi.

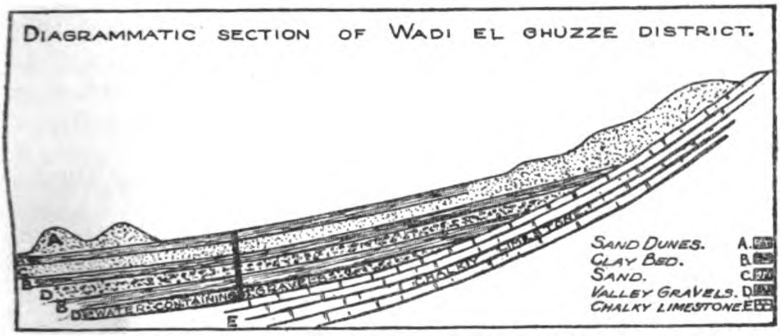


Fig. 4.

The importance of this section for sustained occupation of the front line southward may be inferred from the fact that the springs of Es Shellal yielded no less than 200,000 gallons per day, and apparently the supply continued for the whole period of its occupation by the British forces. The quality varied along this line, the water at Tel el Fara having a salinity of 110 per 100,000, at Um Urgan of 140, while at Es Shellal it rose to 204 per 100,000. It is not easy to explain these variations except on the assumption that the water at Tel el Fara received supplies from a purer source, which diluted the more saline waters derived from the limestone. In this case the possible source of the better waters might be the heavy sand-dune region south of Tel el Fara through which they filtered.

It was, of course, important to know why such large springs existed at Es Shellal. The salinities obtained seemed to indicate that they were independent of the main valley supply, and were connected with large solution effects in the limestone areas toward the hills. In a geological map of Palestine compiled by Dr. Blanckenhorn, an important fault line is shown, extending from Beit Jibrin south-westward to near Abu-Hareira, and about twelve miles from the coast. If this continued hidden beneath the sandy loams and valley deposits of the area filling the Es Sharia and bordering the Ghuzzee drainage

on the east, it would strike the Wadi el Ghuzzee approximately near Tel el Fara, leaving Shellal on the north-west of it. This fault obviously determined the springs of Tel el Hesi (Lachish) and other springs in the north and, considering boring for water, it was suggested that the possibility of its presence should be continually borne in mind. This was especially the case for the area enclosed between the Es Sharia valley, Wadi el Ghuzzee and a line drawn from the junction of the Wadi es Sharia with the Wadi Imleik to Es Shellal. It was believed that large supplies of water of moderate quality might exist there and especially on or about the 300 ft. level, which seemed to be approximately the height of the springs near Lachish and at Es Shellal.

The actual position of the water stream at El Fara, Es Shellal, and Abu Hiseia was not difficult to determine. At El Fara the water was found in shingle, the yield of individual wells in July 1917 being about 100 gallons per hour. At Es Shellal, the water flowing out in beautiful springs was a supply held up by an impermeable calcareous sandstone (sandstone cemented by carbonate of lime) with small yellow flint pebbles, and not subject to evaporation owing to the presence of compact blue clay above it. At the Abu el Hiseia Pools the same succession of clay and pebble beds was noted with layers of compact calcareous sandstone in the series. One of the clays on the west bank was found to be saline. At the main pool there was a clay band in the cliffs just above the water, and also clay in the pool itself, with gravel in between.

Thus, the second great source of water supply for the Gaza front was found in the valley deposits, the water being carried in the gravels and protected from evaporation and diffusion by the overlying and underlying clays. The quality was not so good as that of the waters of the consolidated dunes, and the troops in this section had regularly to drink supplies which, under ordinary circumstances, would be regarded as unsuitable for human consumption.

CHAPTER VIII.

WATER SUPPLY IN MESOPOTAMIA.

THE water supply for the troops in Mesopotamia was mainly derived from the Shatt el Arab, the Tigris, the Euphrates, and from three tributaries of the Tigris, the Adhain, the Diyala, and the Karun. On the upper reaches of the Tigris, above Samarra, the water is comparatively clear from June to November. Lower down at this season there is a certain turbidity due to the constant falling in of the banks. During November the river commences to rise, and usually in April the main flood sets in, bringing down huge quantities of silt. At Baghdad, during the main flood of 1917, the suspended silt was recorded as equivalent to 1 lb. of dried silt in 5 gallons of water. The Diyala comes down in flood earlier than the Tigris, owing to rain in the Persian hills. The Euphrates is more free from suspended matter than the Tigris during the low water months of the year. After it passes through the shallow Hamar Lake, the water at its two mouths, at Qurna and at Magil, is clear throughout the year. The Shatt el Arab, formed by the union of the Tigris and the Euphrates, and receiving on its left bank the Karun, is tidal, but is sufficiently fresh to be potable almost to its mouth. These rivers are polluted, particularly in the neighbourhood of towns and Arab camps. Of 139 samples taken in midstream at Baghdad, 68 per cent. showed lactose-fermenting bacteria in 0·01 c.c. of the water. The tidal water at Basra was worse.

During 1916 shallow wells dug in the river-bank afforded clear water, but, except in one or two instances, they sooner or later failed. Away from the river a few shallow wells were here and there available; others, though used by Bedouins, were too brackish for British and Indian troops. A few useful wells were dug in the Dujailah depression before Kut, and on the old river-bed of the Tigris near Belad. Trial borings sunk in the desert to tap artesian supplies were unsuccessful. When railways were being extended across the desert the whole of the water required by certain camps along the line of advance had to be brought by rail. When motor transport became available, this too was impressed to feed

standing camps in the desert and to render possible the moves that ended in the capture of the Turkish forces at Ramadi.

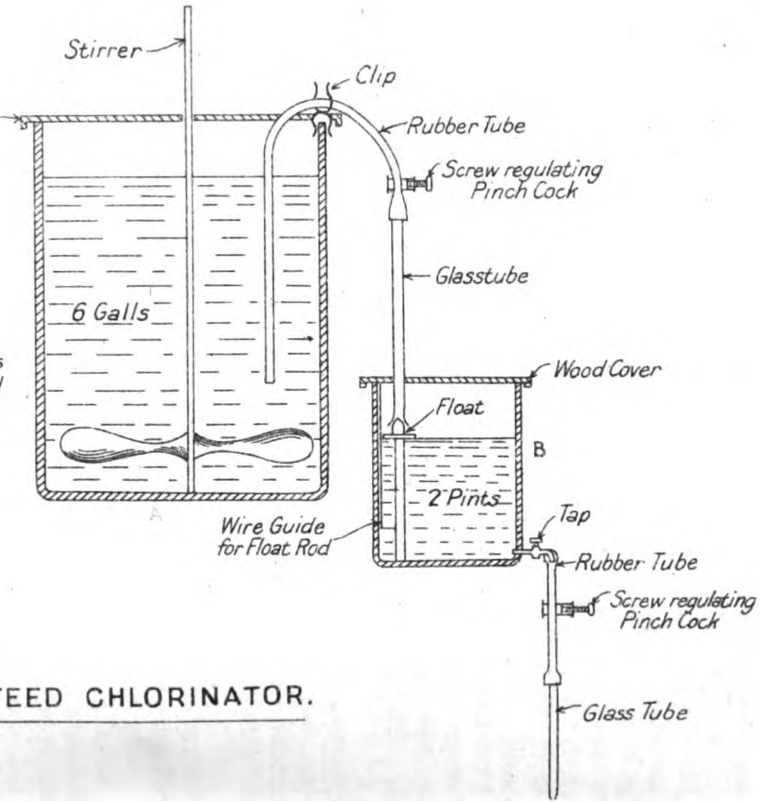
In the early days of the campaign, both within and outside the trench area, there were water stations situated on the river-banks. With buckets and kerosene tins a line of men would fill tarpaulin-lined holes in the ground; or the small inefficient hand-pump, yielding rarely more than 10 gallons a minute, would be laboriously employed. In 1916, in the trenches before Kut, steam and petrol pumps concealed at the river-side adjacent to the front lines were brought into use to fill canvas tanks or tarpaulin-lined excavations. From these, mule tanks and camel tanks, known as pakhals, and army transport carts lined with tarpaulins were employed to convey the water to the troops. In certain cases the water was led along precarious, improvised canals for one or two miles to a camp.

When access to a chlorinated supply of water was impossible, units were supplied with acid sulphate of soda tablets, and prior to operations over enemy areas divisions drew a reserve of tablets to allow of an issue ot four tablets a day for three days.

The Medical Advisory Committee appointed by the War Office, when visiting the front area in 1916, pointed out the danger of supplying water by means of cuts in the ground, which were obviously open to serious pollution. They recommended that piping should be used wherever possible, and that a special medical officer should be appointed to visit and report on all water stations. Captain Morison, I.M.S., was then appointed as officer-in-charge of water examination units, and did much valuable work in co-ordinating the services for the purification of water.

During the attack on Kut, 1916, the 14th Division successfully used a portable Merryweather steam pump to supply its front line with water. At the crossing of the Tigris, when Kut was taken, this pump was brought to the pontoon bridge and was of inestimable value. Later, this type of pump was used in the first advance to Shahraban, when a corporal of the sanitary section of the division had delivered 24,000 gallons of chlorinated water to a brigade of troops within five hours of their arrival at Shahraban on a fiercely hot day.

A high degree of organization was attained at several camp water stations. At first these were arranged by individual units; later the equipments were used to form brigade water stations. A very good example of this type was formed at



General Ratio Recommended of Capacity of A to B: 20 to 1.

N.B. The maximum capacity of A should not exceed 40 Galls. If larger quantities should be required A must be duplicated and connected in series.

FIG. I.

ADJUSTABLE CONSTANT-FEED CHLORINATOR.

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Abu Roman, before Kut. One of still more elaborate construction supplied the 13th Division concentration camp at Amara in the autumn of 1916.

Arrangements on Lines of Communication.—On the lines of communication the formation in 1916 of the electrical and mechanical section of the Royal Engineers, under Major Pitkeathley, R.E., previously a civil engineer under the Government of India, and later the director of the section, created a revolution in the system of water supplies.

Old Turkish pumps were repaired. New pumps were installed. Pipe-laying feats, each attempting to beat the previous record, followed one on another so frequently as to become commonplace. The allowance of treated water which, in 1916, was estimated to be under one gallon a head, rose till in 1918 the pumps and filter plants at Basra were capable of yielding over a million gallons of treated water a day, and the supply to hospitals and camps was unstinted. At least one hospital in the Makina camp, over a mile from the river, used 20 gallons per head.

At Amara, until 1916, water was drawn by hand from the river. In that and in the following year, wells were dug on the right bank. In 1917 a precipitation plant and pipe-line were installed at Pindi Point, and, worked in a manner which will be referred to later, gave surprisingly good results. In 1918 an excellent filter plant and pipe-line were brought into use for the hospitals and camps on the right bank. At Baghdad, old Turkish pumps were taken over when the city was captured in April 1917. At seven different intakes these delivered crude river water into nine different pipe-lines, and gave a limited and intermittent supply to every part of the city. These pumps and pipe-lines were repaired or replaced. Arrangements were at first made to clarify and to chlorinate by hand the water supplied to billets. Subsequently, chlorination was effectively accomplished at the intakes, and by the end of 1917 the whole population, Arabs, Armenians, and Jews, as well as British and Indian troops, were receiving a supply of treated water that could be raised to over 1,000,000 gallons a day. More ambitious schemes to raise the volume still further, and to improve the quality were being elaborated at the time of the armistice.

Clarification of Water.—The removal of the silt from the water early attracted attention. Probably erroneously, as later experience showed, the severe dysenteries and diarrhœas of the early part of the campaign were attributed to it. It

came from two sources. During the flood season it was brought down by the melting snows and, passing through the limestone hills of Armenia and Persia, was found to contain 33 per cent. of calcium carbonate at Baghdad. During the low water season it was entirely due to erosion of the banks. Of fine colloidal clay there was very little even during the worst floods. Settlement for forty-eight hours was sufficient to clarify the water, and this was more rapidly effected by the use of alum. The improvised tanks, whether excavated in the ground or made of canvas supported by posts, and later the iron tanks, were arranged in pairs to work in series or alternately. If in series, the clarification by alum was accomplished in the first tank. The clear water was then syphoned off to the second, where chlorination was effected. If the alternate arrangement was used, chlorination took place first, and half an hour later in the same tank alum was added, and the tank was then left undisturbed till it was ready for use.

In practice, the dose of alum was ascertained empirically. Generally, a handful of alum was placed in a muslin bag and was drawn to and fro on the surface of the water in a tank till flocculation was seen to begin. In December 1917, it was established for the Tigris water that the greatest degree of clearness was most rapidly obtained by using a dose which was equal to half the alum necessary fully to react with the alkalinity of the water. Reasonable clearness could be obtained at certain doses below this ; while at intermediate doses, the clarification was neither so good nor so rapid. The lowest of these satisfactory doses, about five and a half parts of aluminium sulphate per 100,000 parts of water, was later officially recommended for general use. At Amara, the alum solution was run into the suction pipe of the riverside pump, which fed the precipitation tanks, in a dose which was maintained at that given by the above rule. After settlement, the crystal clear water was lifted by a pump, fitted with a chlorine feed, to the overhead distribution tank. This water equalled in sterility that delivered by the best filters.

Sterilization of Water.—Sterilization of the drinking water was not seriously considered until 1916. Early in 1915, Captain J. J. Harper Nelson, I.M.S., who was serving with the 6th Division, introduced a portable apparatus to deliver a definite weight of chlorine made from potassium chloride and hydrochloric acid. The chlorine, dissolved in a known quantity of water, was added to a certain volume of the water to be treated. So strong, however, was the prevalent

view that cholera, dysentery, and diarrhoea were diseases spread by contact, flies and food, and by these alone, that in May 1916, officers arriving in Mesopotamia were handed a circular setting forth rules for the preservation of health, but informing them that river water drawn a little way from the bank was fit for drinking if clarified by alum. Chlorination was not officially taken up until it was shown that the cholera at the front, at Ali Garbhi, at Makina and at Abadan, had distributions which could only be explained by infection from water mostly drawn directly from the river, and that this also explained the outbreak of epidemic jaundice and cholera at Nasiriya.

Captain Nelson's method was widely used. A drawback to the apparatus was that it was designed at first for comparatively small quantities of water. It had afterwards to be used to treat supplies for whole brigades and divisions and the labour involved was very great.

On the suggestion of Major F. P. Mackie, I.M.S., bleaching powder was introduced. The bleaching powder in Basra in May 1916 was roughly packed in rectangular wooden cases most of which were broken, so that the powder almost entirely lost its free chlorine. The next consignment arrived in jars, repacked in Bombay, and in ¼-lb. tins from England. No two packages, however, even from the same case, had the same chlorine values, which varied from about 20 per cent. to less than 1 per cent. of available chlorine.

Previous to May 1916, units had no uniform standard for the treatment of drinking water. In July 1916, however, a small laboratory was opened at the Nakib's House, Basra, and the study of bleaching powder was taken up, with the result that a standard solution of chlorine to contain 1·28 per cent. available chlorine, was devised by Captain Morison to meet these conditions. This was shown to be sufficiently stable and its use was officially authorized. The solution was prepared in bulk by sanitary sections. Churns were constructed by mounting lime juice kegs on iron stands. Later these were replaced by large milk churns. The wood was protected by bitumen from the bitumen wells at Hit, thinned with petrol to the consistence of paint. Bleaching powder of any chlorine content above 4 per cent. was placed in the churn and water was added till the churn was three-fourths full. The churn was then rotated and the chlorine was extracted. The sludge was allowed to settle and the clear liquor was run off and diluted to the standard strength. The sludge was

rewashed once or twice and the washings were used to churn the bleaching powder which was to be treated next. The standard liquor was bottled in ordinary corked bottles or placed in jars with the following label:—

"*Bleaching Powder Solution*.—Do not use when over a fortnight old.

For tanks and water-carts, add one ounce (two tablespoons) of this solution to each 100 gallons of water. Stir well with a paddle for at least two minutes. Wait twenty minutes and test with starch-iodide solution before using the water.

For pakhals, kerosene oil tins and other small receptacles, dilute the solution before use as follows: Add one ounce of the solution to an empty bottle and make up to one pint with water; shake thoroughly.

The doses of this dilute solution are:—

Half a dram for a water bottle (1 quart) = Half a teaspoonful.
One ounce for a kerosene tin (4 gallons) = Two tablespoonfuls.
One and a half ounces for a pakhal (6½ gallons) = Three tablespoonfuls.
Half an ounce for a chagal (2 gallons) = One tablespoonful."

The above dose gave 0·8 part of chlorine per million parts of water, a dose which bacteriological tests had shown to be sufficient for most waters of the type found in Mesopotamia. It was controlled, however, by the use of the potassium iodide and starch test to demonstrate the presence of free chlorine in the water twenty minutes after the addition of the chlorine solution. If no colour was found, the dose was increased and each additional dram of solution per hundred gallons corresponded to an increase of 0·1 part of chlorine per million parts of water. The dose in decimal parts of chlorine per million parts of water required for a particular water could be ascertained by a modification of the original test suggested by Professor Sims Woodhead. By the middle of 1917 the use of the standard chlorine solution had been extended to all parts of the force.

The application of bleaching powder solution to large supplies was solved by the invention of the "suction chlorinator," a simple device for feeding the solution to the suction pipe of a water pump (Fig. 2). The invention arose in May 1916 out of the necessity of introducing the solution into the inaccessible water tanks of the little hospital ship "Ardlui." The first device was to connect a kerosene tin by a small copper pipe and stopcock to the suction pipe of the steam pump. The diameter of the feed pipe was selected so that the kerosene tin, filled with the necessary amount of solution, should empty in the time taken to fill the water tanks. A similar device was then fitted on the hospital ship "Coromandel" and in August 1916 another was fitted on the Magil supply at Basra. A needle valve working inside the solution tank, now of larger size, was devised by Lieutenant Meyer, R.E., of the electrical and mechanical section, and in 1917 the

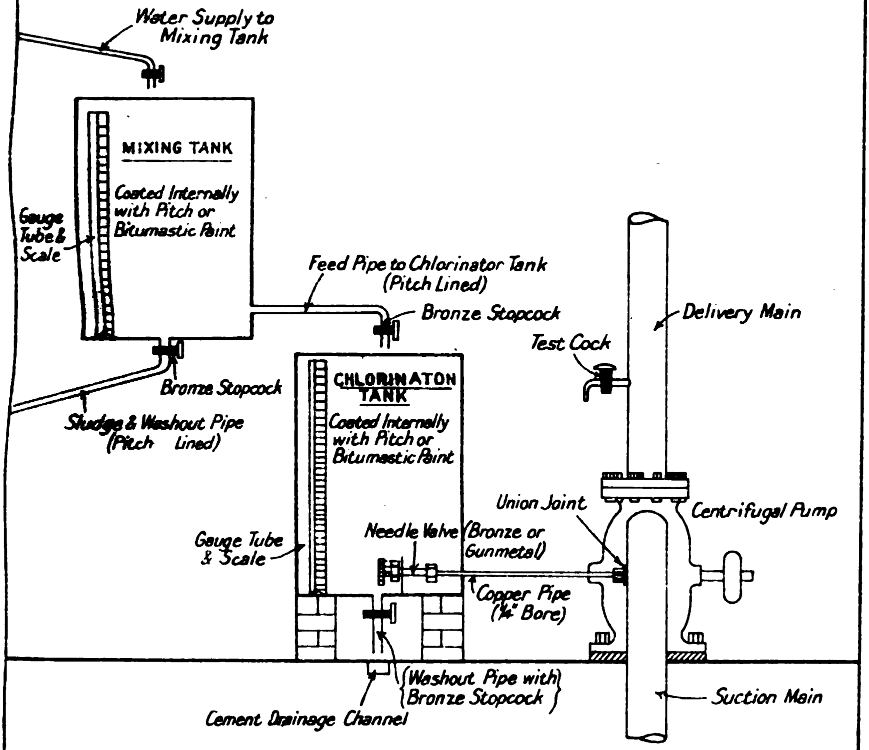

FIG. 2.

DIAGRAM SHOWING ARRANGEMENT OF A SUCTION CHLORINATOR.

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Malby & Sons Lith.

needle valve was placed outside the tank and was much improved by Private A. M. Brin, R.A.M.C., previously an analytical chemist with the Great Western Railway at Swindon, and by Corporal R. H. Carter, R.A.M.C., who had been a lecturer in agricultural chemistry at Reading University. The device was brought to a high degree of efficiency. The dose of solution was controlled by adjusting the bronze needle valve so as to give a dose of chlorine which, in a sample taken from the delivery pipe of the pump immediately after chlorination and allowed to stand for half an hour, gave a definite blue colour with potassium iodide and starch. This colour was matched by comparison with a colorimetric series, made by adding known amounts of chlorine to the untreated water. It was possible within the range of doses used, to adjust the dose to within a decimal part of chlorine per million parts of water. It provided also a method of calculating the throw of centrifugal pumps against a head when reliable gauges were not available. The chlorinator did away with the dangers attending hand chlorination by unskilled persons.

Early in 1917 all the intakes at Basra were fitted with chlorinators. In April 1917, one was taken to Baghdad but chlorinators were not taken into use there till November 1917, when the epidemic of cholera was shown to be derived from the river.* In 1918 it was adapted to certain of the pumps used by the army and at the end of that year it was computed that over two million gallons daily, or three-fourths of the whole water supply in Mesopotamia, were being treated in this way. Chlorination of unfiltered and unsettled water at the intake gave surprisingly good results. At Baghdad out of 422 samples taken from the water supplied to the indigenous population as well as to the troops, 32·9 per cent. gave no lactose fermenters in 100 c.c. of the water, a standard comparable in its bacterial content with a good muncipal supply in England. Forty-six per cent. gave no lactose fermenters in 10 c.c., and 16·8 per cent. gave none in 1 c.c. It will be recalled that 68 per cent. of the samples from midstream at this point gave lactose fermenters in 0·01 c.c.

The character, as well as the regularity of the supplies of bleaching powder caused much anxiety from time to time. The 4-oz. tins, which were used with success in France, had usually little or no chlorine when opened in Mesopotamia. Glass bottles containing from 4 to 7 lb. gave chlorine values

* See p. 120, Vol. I, Diseases of the War.

that varied from 6 to 15 per cent. Consignments in stone jars holding from 14 to 30 lb., were better quality. The best of all was bleaching powder supplied in steel drums containing 1, 2, and 3 cwt., but it was only rarely that supplies came in these drums. The arrival of consignments was also very uncertain. In August 1916, the stocks at the base were completely depleted, but fortunately a consignment which had not been expected or notified was being unshipped at the time. In September 1917, the position was even graver at Baghdad, for with the arrival of 2 tons of bleaching powder which was found to have lost its value came the news that, owing to enemy action, no further supplies were expected for at least two months. Major Pitkeathly took the situation in hand and under his personal supervision experiments were initiated, as the result of which troops in the Baghdad area were being provided within a week with electrolytic solution made in improvised cells.

Five divisions in the front line had still to be supplied with chlorine solution. Four cylinders, each containing about 70 lb. of liquid chlorine, were known to be in the ordnance stores at the base, although it was not known to what department or for what purpose they had been consigned. They were hurriedly brought up to Baghdad, and experiments in the preparation of bleaching powder or bleaching solution were undertaken. After a few failures a dry bleaching powder containing from 25 per cent. to 34 per cent. available chlorine, according to the quality of the lime, was turned out at the rate of 60 lb. a day. Two days' production was sufficient to supply a division for a month, and for two months the whole of the forward line used Baghdad bleaching powder, packed in bitumen-lined kerosene tins. The preparation of bleaching powder was resumed again in October 1918, for a few weeks, to meet another emergency.

The electrolytic plant became a permanency, and was greatly improved and developed by Lieutenant A. J. Keast, a chemist from Broken Hills, Australia, who had been sent out with the filtration plants. To his energy, too, was due much of the excellent organization of the chlorination in the Baghdad area, and later in the difficult Persian line of communication. At the armistice a second plant was ready to supply electrolytic chlorine at Basra, but by this time some of the spare Wallace and Tiernan controls were being fixed at the Basra pumping stations and liquid chlorine was coming into use.

Though mechanical chlorination was first used on two

river hospital ships, and though the filter plants were sent out by the Inland Water Transport Department, primarily for the use of its fleet, hand chlorination of river water in the ships' tanks with the standard bleaching powder solution by men of the river ambulance service was continued on most ships up to the time of the armistice.

In May 1916, on the recommendation of the Director of Medical Services, the military authorities applied by cable to the War Office for four water purification barges, similar to those which were in use in France, to be sent out to Mesopotamia, accompanied by a trained personnel. The whole question of the water supply in Mesopotamia was then considered by a committee at the War Office, and the details were worked out by the officers who had been responsible for the design of the barges sent to France. On their advice the Army Council replied to the effect that the rivers in Mesopotamia should be divided into convenient sections by a system of water posts, at which purification of the river water should take place continuously by means of stationary or floating filtration plants, which would deliver the purified water into storage tanks, and that in order to form the water posts, four barges and seventeen other plants would be sent to Mesopotamia as soon as possible. For storage purposes 12 tank barges, each having a capacity of about 10,000 gallons, were to be sent out to act as tenders to the filtration barges, together with light cylindrical tanks, which were made in sets of progressive diameter, so as to nest into one another for transport, and might be used singly or coupled together in any required number to provide a reserve supply. For purposes of distribution, piping and high-pressure pumps, capable of delivering water to a considerable distance in case of necessity, were also to be despatched. As the barges had to go by sea, it was necessary to provide larger vessels than those used in France, and, consequently, owing to the greater space on them, a filtration plant capable of delivering 8,000 gallons of pure water hourly was installed in each. Sterilization of water by means of chlorine gas had, as already noted, proved very efficient in France, and it was decided to fit the new vessels with chlorine gas cylinders and the Wallace-Tiernan apparatus. To remove excess chlorine, when necessary, cylinders of sulphur dioxide were provided. It was considered by the War Office authorities very unlikely that attempts would be made to poison the river waters, and special treatment tanks for the elimination of poisons were, therefore, not provided for any of the stationary

plants. The tanks were, however, placed on the barges, as they would be found useful for the injection of soda carbonate, alum, or in the case of need, chloride of lime and sodium sulphite into various points on the purification system.

The barges had the officers' quarters and a well-fitted laboratory on the deck aft, and below these the engine stores and the engines working the pumps were placed. Amidship, there were two large settling chambers, each having a capacity of 5,000 gallons, four "Bell" filters, and a large chlorinating tank holding 4,000 gallons. Forward on deck were placed the open chemical tanks and the quarters for the crew; below the open chemical tanks were the closed chemical tanks, from which, by air pressure, any required solution could be injected into selected points of the pressure purification system. Beneath the men's quarters were placed the chemical and hose stores.

The water to be purified was taken from the river, and suction pipes were placed on each side of the barge so that the water might be taken from either side. Water might also be pumped to the barge by means of flexible pipes and suction branches on deck from an outside source, if necessary. After passing through a rough strainer the water was directed through a meter, then through a Venturi tube, by means of which lime water might be sucked into the system, and so into the first settling chamber. The water passed upwards through the first settling chamber, left it at the top and entered the second settling chamber near the bottom, passing upwards through it and thence to the filters. In the connection between the settling chambers and the filters there was another Venturi tube, through which lime might be introduced if required. It was possible, by means of the pipes and valves, to use the settling chambers in parallel instead of in series, and also to cut out either cylinder and pass the water through the other independently. The water entered the filters at the top, passed out at the bottom, and thence was conveyed to the chlorinating tank or contact tank. Between the filters and the chlorinating tank was the chlorine gas diffuser in its special casting, and here the gas was introduced. After passing through the chlorinating tank the water entered a casting in which was placed the sulphur dioxide diffuser, by means of which SO_2 gas could be introduced to remove any excess of free chlorine. After dechlorination the water passed right and left to the distribution mains on deck, whence it was conveyed by hose pipes as required. The chlorine gas cylinders were placed in a special compartment close to the

laboratory. The Wallace-Tiernan chlorine control apparatus was placed in the laboratory itself, where it was always under the immediate observation of the chemist in charge of the boat. The sulphur dioxide cylinders and the special control apparatus were placed in a special chamber on the deck level and adjacent to the diffuser casting. During ordinary working, alum and sodium carbonate were introduced between the pumps and the first settling chamber, and the chlorine gas and sulphur dioxide through the special diffusers as already mentioned. But by means of the chemical tanks and injection cylinders, chloride of lime solution could be introduced into the system just before the chlorinating or contact tank, in the event of any breakdown of the chlorine gas or SO_2 apparatus, and sodium sulphite could be added immediately after the water left the contact tank. The laboratory was well fitted up for chemical and bacteriological work, and special lines were taken from various points on the system to taps over the sink. The working of the plant could be easily controlled by taking specimens from the taps at frequent intervals. The plant could run continuously for twenty hours with a steady delivery; at times, according to the amount of sediment in the raw water, the settling tanks required to be emptied and the filters back-flushed.

Barges fitted with Ransome-Ver Mehr plants were on similar lines. The main suctions were taken through the ship's side instead of on to the deck, and the settling cylinders were always used in series. Two of Ransome's solution apparatus for alum or sodium carbonate were also provided, in addition to the ordinary tanks and injection cylinders.

The stationary plants were made by four different firms. The general plan of working was similar in all of them. The water from the river was pumped into settling tanks, which were used as continuous settling tanks, half the water passing through each tank. The raw water received a dose of alum, and if necessary, soda, and was then distributed by means of troughs so adjusted that the water flowed in a very thin film. The tanks were provided with surface baffles and floor baffles. The settled water was collected by troughs similar to those used for distribution, and flowed to a small sump, whence it was picked up by separate pumps and conveyed to the filter. After leaving the filter the water received the necessary dose of chlorine gas and then passed into the chlorinating cylinders, which were of sufficient size to enable the chlorine to act for the required "contact" time. After

leaving the cylinders sulphur dioxide gas was injected into the water to remove excess chlorine, after which the water passed into overhead tanks and was drawn off as required. The special alum and soda apparatus manufactured by the maker of each kind of filter was provided. Chemical solution tanks were installed, in which chloride of lime or sulphite of soda, if required, could be injected into the system, as in the case of the barges, by means of compressed air chambers connected with the chemical tanks. A small laboratory and chemical stores were provided at each station, and the chlorine gas and sulphur dioxide apparatus were placed in the laboratory, to which also were brought pipe-lines from the sedimented water, filtered water, chlorinated and dechlorinated water, so that the working of the plant could easily be supervised. The maker supplied two plants, delivering 13,200 gallons per hour, six plants delivering 5,000 gallons per hour, and three plants delivering 1,760 gallons per hour; another, three plants delivering 5,000 gallons per hour; a third, two plants delivering 2,000 gallons per hour, and the fourth, one plant with the same delivery. The first also provided two plants delivering 5,000 gallons per hour, to be erected in barges on the lines already described. The subsidence tank, however, was a single horizontal cylinder. The same firm also constructed a small plant delivering 400 to 600 gallons per hour; this was originally intended to be mounted on a motor chassis for use in France, but was found to be too heavy for the roads. It was accordingly sent to Mesopotamia to be installed in a small barge, which might be able to supply water at points to which the large barges could not proceed.*

All the plants were put together in England and thoroughly tested by Lieutenant T. Sugden, R.E., a chemist who had received bacteriological training in the Royal Army Medical College. The barges were taken to Richmond for the water tests and worked by the officers and chemists who would have charge of them in Mesopotamia. During the trials there were heavy floods on the Thames and the water contained much suspended matter. No difficulty was experienced in obtaining a perfectly clear filtrate which after adequate chlorination was not found to contain *B. coli* in 100 c.c. On completion of the trials, owing to the submarine menace, the machinery was taken out of the barges and sent out as cargo; the barges were decked

* Full engineering details of the barges and stationary plants will be found in the Report on the Mesopotamia Water Supply, published in 1918 for the Department of Inland Waterways and Docks at the War Office.

over and taken out to Mesopotamia by tugs. All the barges arrived safely at their destination and were refitted at Basra. (Fig. 3.) Two of the barges remained at Basra and were used to supply water to the base. One was sent up to Baghdad where it supplied the hospitals pending the erection of a land

Fig. 3.—Filtration and sterilization barge on the Tigris.

plant there. On completion of the land plant it proceeded 40 miles up the Tigris to Akab until the camp there was moved. Then it was brought down to Chuldari where it was proposed to lay out a cantonment. The fouth barge also proceeded up the Tigris and stopped at Karrada on the left bank between Baghdad and Hinaidi. From there it went up to Chuldari, and on the arrival of a second barge at Chuldari it was sent down to Amara where there was a concentration camp. The seventeen land plants were distributed as follows:—

The two "Ransome" large plants delivering 13,700 gallons per hour.	One to Magil near Basra. One to the advanced base on the right bank of the Tigris below Baghdad.
The three "Bell" plants delivering 5,000 gallons per hour.	One to Ramadi on the Euphrates. Two to Amara on the Tigris.
The six "Ransome" plants delivering 5,000 gallons per hour.	One to North Baghdad two to Kut-el-Amara, one to Nahr Uman, two to Hinaidi.
The three small "Ransome" plants delivering 1,600 gallons per hour.	One to Hillah on the Euphrates. One to Ahwaz in Persia. One not allotted.

Three small plants made by other firms were not allotted, as they arrived late and were too small to be of much value.

The two floating plants delivering 5,000 gallons per hour were fitted into barges built at Basra, and one was sent to Amara, the other being kept at Basra.

The small 400 to 600 gallon per hour plant, originally designed by the Ransome firm for motor transport, was allotted to the base isolation hospital.

The filtration barges did excellent work; but unfortunately did not arrive in time to be of service when the main body of the force was operating along the deeper waters of the Tigris. Their heavy draft rendered them useless for transport up the Tigris very far north of Baghdad or to the Euphrates through the Hamar Lake, or up the Diyala river. They were consequently mainly used on the lines of communication.

The plants as a whole worked exceedingly well, though at first they were looked upon as somewhat of a luxury. The "Bell" type was the most popular, owing to its simplicity. The most notable feature of the Ransome plants was the automatic washing device but, except on the plant delivering 13,700 gallons hourly at Magil, it was never used. Approximately twenty-four hours' settlement of the raw water before filtration was provided on all plants, with the result that the water delivered to the filters contained very little suspended matter and a plant working eight to ten hours daily could with ordinary attention work for a fortnight to three weeks without washing back. Obviously under these conditions the continuous washing of the filters was unnecessary. The raw water was usually settled without alum and a charge on the filters after washing was often sufficient to give a perfectly clear water for the rest of the run. The plant at Magil worked continuously until the beginning of 1919. The drifting then stopped and it was found that the bottom of the pipe which carried the raw water and washed sand to the top of the filter had been completely worn away by the moving sand. This was replaced locally and the washing re-started.

Chlorine gas and Wallace-Tiernan gauges were used on all plants. Some of the gauges suffered in transit but the rest proved a success and quite justified their cost, as under the existing conditions it would have been inconvenient to work the plants with bleaching powder. A fault in their construction was the unsuitability of the cement used in the carborundum diffusers. This was slowly attacked by the chlorine and the diffuser finally fell to pieces in consequence. A number of spares, however, had been supplied, so that no inconvenience beyond occasional inspection of the diffuser in use was caused.

The dose of chlorine depended on the position on the river, the condition of the mains, and whether the water was filtered or unfiltered.

In November 1916, the Central Laboratory, Basra, was established, and one of the officers was officially placed on water supply duty. The training of officers and men from certain sanitary sections was begun, and analyses of the river water were recorded from day to day. In April 1917, the water section of the laboratory was transferred to the Central Laboratory, Baghdad, and thereafter it was in direct touch with the A.D.M.S. (Sanitation) at General Headquarters. Its members were sent to inspect and advise in every part of the field. Classes of instruction in the titration of bleaching powder the preparation of solution, the various methods of chlorination and the use of alum were then in constant progress and were strictly limited to four students at a time to permit of individual attention throughout the day. There were no lectures; all the tuition was carried out at the laboratory bench or at a pumping station. All bleaching powder arriving from Basra for Baghdad and the divisions at the front was examined and distributed. The preparation of bleaching powder took place in the Central Laboratory, as also the analyses of well waters sent by the field force, day to day analyses of the river and the treated supply, and investigations into limes, gypsums and cements for the Royal Engineers.

In spring, 1917, the water section of the Central Laboratory consisted of an officer, two British other ranks, both of whom were highly skilled chemists, and an Indian follower. In March 1918, it was designated the Water Examination Unit, and officially attached to the army troops section of the force.

In 1917, twenty-four chemist officers, with chemist corporals and enginemen for the filter plants, arrived. They were attached to the Inland Water Transport section of the Royal Engineers, but after a short time with it, and subsequently with the R.A.M.C., they were finally attached to the electrical and mechanical section of the Royal Engineers. This section then took over the treatment as well as the provision of water throughout the lines of communication. The officer in charge of water examination became the liaison officer between the Director of Medical Services and the Director of the Electrical and Mechanical Section, thus securing co-operation between the two branches of the service.

CHAPTER IX.

WATER SUPPLY FOR BRITISH TROOPS IN ITALY.

THE positions occupied by the British troops in Italy were on the Asiago Plateau and on the Venetian Plain. The former was at an elevation of 3,000 ft. above the sea-level, bounded on the north by steep hills, rising to a height of 5,000 to 6,000 ft., and on the south by more gently sloping hills averaging some 4,000 ft. above the sea, with a descent through foot-hills and escarpments to the Venetian Plain. The northern and southern boundaries of the plateau are composed of a calcareous limestone of the lower Jurassic formation. The important characteristic of this limestone was its permeability, with a resulting absence of natural springs. The plateau itself is composed almost entirely of another variety of calcareous limestone belonging to the lower cretaceous system. It was mostly concealed by a light covering of soil and was also very permeable. Both limestones were extensively fissured. As a direct result of this geological formation, the plateau was noted for an almost entire absence of springs. "Dolines," *i.e.*, shallow and deep surface pans or depressions, were an outstanding feature; they rapidly collected water, which shortly afterwards disappeared through the permeable substrata. Practically all the rain and melted snow were rapidly lost through the numerous fissures. There were a few small springs, but these were in enemy hands.

At the lower levels of the foot-hills and escarpments there were several good springs. The delivery of water varied throughout the year and corresponded with the rainfall. The larger springs were, however, less liable to rapid fluctuations than the surface springs. Owing to the highly fissured nature of the limestone impurities readily gained access to the spring waters, which, after heavy rains, became slightly turbid. Generally, half a standard measure (15 grains) of chloride of lime was found sufficient to sterilize the waters.

The supply of water to the plateau was, therefore, mainly an engineering problem, pumping plant being established at each of the main springs to lift water direct to the summit of the mountains, whence service reservoirs fed the plateau area by gravity. Where direct lift was not possible pumping stations were established at intermediate levels. Sites for storage reservoirs on the summit were selected where

they were not under direct observation from the mountains held by the enemy. Four 9,000-gallon tanks were erected with timber floors and sides, and lined with tarpaulins, 30 ft. square. From the summit reservoirs the pipe-line descended to the first water point, which was situated 2,000 yds. from the reservoirs, at a level of 750 ft. lower. Immediately below the first water point an automatic pressure reducing tank was installed. From this pressure reducing tank a 4-in. main was continued through forest to the front line, supplying several water points on its way. All tanks supplying water points were placed 20 to 30 ft. above road level, thus greatly facilitating the filling of the water-carts.

As the tarpaulin-lined tanks were quite unsuitable in winter, special tanks of masonry and concrete, rectangular in form, with a 6-ft. depth of water, were constructed. The roofing of the tanks consisted of rolled steel joists, carrying a 6-in. layer of concrete, reinforced with expanded metal and covered with a 2-ft. layer of stones and earth. These winter tanks, together with the draw-off pipes, were specially protected against frost, and were so arranged that they could be completely emptied as required, especially for cleansing purposes.

On the Venetian Plain water-supply work was mainly concerned with the erection of water-cart refilling points. Villages along the foot of the mountains were generally found to have more or less satisfactory supplies. In some cases additional sources were tapped and, with the head available, 2-in. delivery mains were rapidly laid. The water points were formed of a pair of 400-gallon galvanized iron tanks connected together and raised on framing high enough to enable the carts to be filled. Inlet pipes to the tanks were fitted with 1-in. or 2-in. ball valves, so that the tanks refilled automatically. The 2-in. delivery pipes had a length of flexible hose to discharge the water into the carts. In areas where there was no great concentration of troops, an 800-gallon storage tank was generally sufficient. In villages where good wells existed, petrol motor pumps delivered the well water into 400-gallon tanks, from which the water-carts were filled by hand pump. In a belt of country running as far south as Dueville, many artesian or tubular wells were found. They supplied the casualty clearing stations, as well as troops, from a service tank, with sufficient head to fill by gravity tanks of 400 gallons capacity, which were erected at the casualty clearing stations.

At some railheads troops were supplied with water from lorries fitted with a length of 2-in. piping, to which ¾-in.

bibcocks were fixed for filling the water-bottles. At the more important railheads 400-gallon tanks were erected. They were filled from the nearest source of water supply, which was frequently a long way off so that the water had to be carried by rail over considerable distances. For water carriage by rail special water-transport waggons, designed to hold about 3,000 gallons each, were employed.

Reinforcement camps and various G.H.Q. schools were supplied from local springs, the water being conveyed from refilling points by water-carts. The supply from this source was, however, only sufficient for drinking and cooking purposes. Water for ablution was drawn from a small river, the water being pumped up to a 9,000-gallon canvas-lined storage tank on the hillside above the camps and buildings.

A peculiar meteorological feature was the seasonal alteration of " dry " and " wet " belts, in consequence of which, during the dry and summer months, special provision had to be made for the maintenance of an adequate water service for troops concentrated in certain areas. Difficulties were often avoided by a knowledge of this peculiarity, troops being concentrated as far as practicable in areas or zones which were sufficiently water-bearing to meet all local needs during a continuation of dry weather. But with a sufficiency of motor transport no insuperable difficulty in water supply was ever likely to occur in the British positions on the plain, although it was always desirable for military reasons to avoid, as far as possible, congestion of the roads by water traffic.

At the suggestion of the D.M.S., a Water Board Committee, consisting of a representative of the Quartermaster-General, the Water Officer on the staff of the Engineer-in-Chief, and the A.D.M.S. (Sanitation), was formed. The Board met once or twice weekly to discuss all matters connected with the water supply, and made recommendations to the Engineer-in-Chief and the Director of Medical Services.

At the first meeting of the Water Committee, the general situation in relation to water supply was considered. A map showing the existing sources of water supply, such as wells and springs, and a table giving the quality and quantity at each point, obtained from the representatives of the Italian Public Health authorities attached to the Italian General Headquarters, were issued by the Engineer-in-Chief to the chief engineers of corps, and by the Director of Medical Services to the D.Ds.M.S. of corps for circulation to sanitary sections. Instructions were issued to corps pointing out the necessity

for special precautions as regards drinking water, in consequence of previous outbreaks of cholera and the prevalence of diarrhœa among the troops. Only water supplies shown on the table as " potable " or " fit " were to be used. The D.M.S. arranged for the sanitary sections to examine sources shown on the map which were not considered fit for drinking purposes, and to re-classify them where necessary. Private sources not mentioned in the map and table, many of which had a good supply, were also tested and classified.

It was ascertained that the XIVth Corps was supplied from the Brentella Canal, the crude water being pumped directly into the undamaged portion of the system of mains and reservoirs in the Montebelluna, Trevignano, Volpago Arcade area as the drinking water supply both for the troops and civil population. At the time there was a large number of cases of typhoid fever and diarrhœa amongst the latter. The Brentella Canal was fed directly from the River Piave in the neighbourhood of Pederobba, and above this point the Piave was in enemy hands. The original source of supply was a water distribution system at S. Lorenzo, which was in possession of the enemy, who had cut the main. A second source of supply from the River Curogna at Onigo had failed, owing to the damage of the pipe-line between Onigo and Cornuda by shell fire. It was on account of this that water had to be taken from the canal. A third source was from shafts sunk by the Italians in the Piave river-bed at Covolo, from which water was pumped into an old covered concrete aqueduct running through Biadene along the southern bank of the Brentella Canal. A minor source of supply was obtained from a spring on the Montello, where a supplementary reserve was created.

For the general control and distribution of drinking water in the advance area, the A.D.M.S. (Sanitation) recommended that a barrage should be built in the River Curogna at Onigo, to impound a sufficient quantity of quiescent water in such a way that no disturbance would take place during heavy rain; that the impounded water should be passed through roughing filters, which were to be cleansed daily by a reverse flow of water and treated with a strong solution of chloride of lime, to be washed away before the filter was again used for filtration purposes; that the filtered water should then be treated with standard emulsion of chloride of lime, by means of a special drip-feed apparatus, and a contact tank of one hour's storage capacity constructed to receive the filtered and chlorinated water; and that the treated water should be

distributed by pipe-line throughout the front line system of mains and reservoirs, serving both the French and British zones.

Further, in order to provide time to repair the pipe-lines damaged by shell fire between Onigo and Cornuda, it was recommended that reservoirs of a capacity to hold at least one day's supply should be constructed in the neighbourhood of Cornuda, on high ground, so as to serve as a gravity source of supply for the whole of the pipe-line system. Pumping of crude water from the Brentella Canal was then to be prohibited, but if it became necessary to use this source of supply, it was to be treated in the same way as the water impounded in the barrage at Onigo.

These recommendations were approved and work was commenced. Filters were also constructed at Biadene, and the filtered water was chlorinated. A contact tank was constructed to hold the filtered and chlorinated water before it passed into the distribution mains by gravity to a reservoir at Montebelluna, and also to the pump house at Biadene, where it could be pumped towards Cornuda for the Crespignaga and Caerano branches. These works were regarded solely as a reserve supply in case the Curogna river supply was cut off. As the Curogna river ran through the area of the tenth French Army, a joint sanitary patrol of French and British troops was appointed to safeguard its banks from being fouled.

Later, in view of the developments made with regard to springs in the Maser area, the schemes above described were modified and the following works were carried out (Fig. 1):—

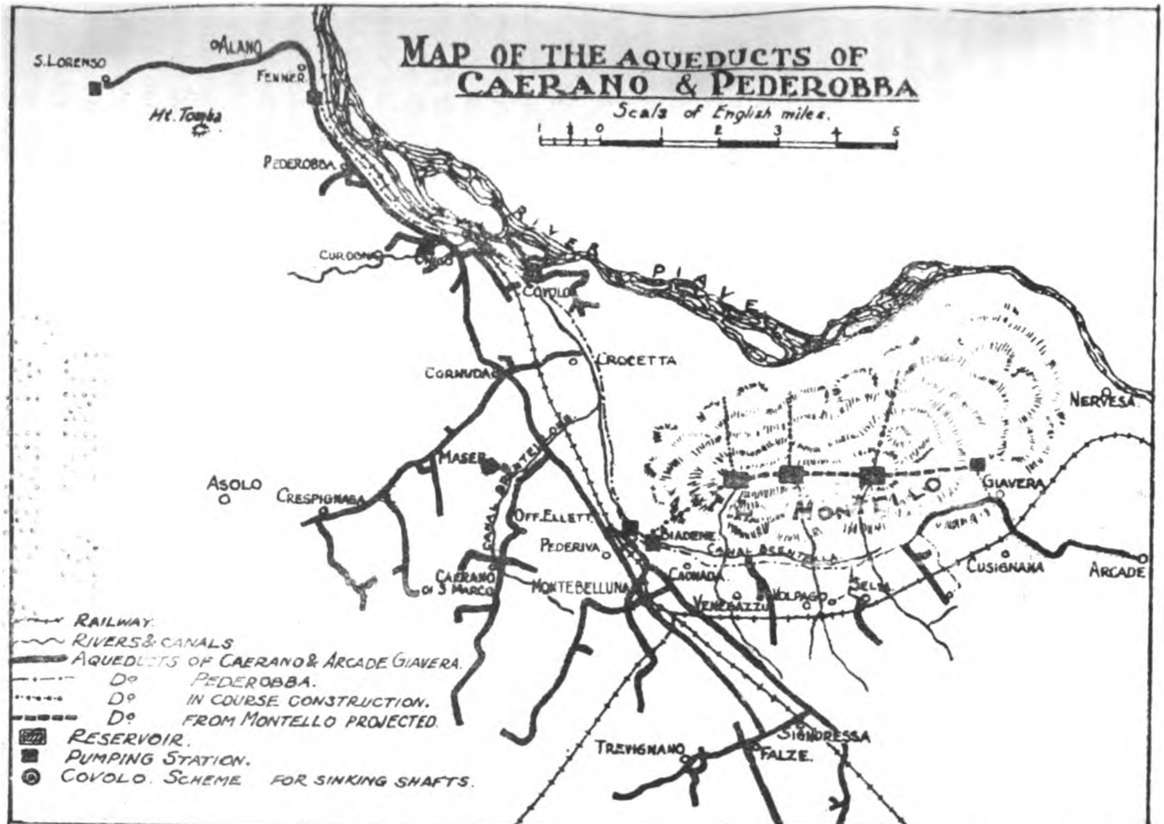
(1) The existing pumps and pump house at Onigo were maintained and worked as long as possible, Curogna water being pumped direct to new filters at Biadene.

(2) The two branch lines supplying Crespignaga and Caerano were cut off from the main, so that all water from Onigo passed directly to the filters at Biadene, and all stand-pipes along the main between Onigo and the filters were cut off.

(3) For the two branch lines supplying Maser and Caerano in the area occupied by the French Army, the springs at Maser were used and the water was turned into the existing mains, which were also connected to a new line between Maser and Caerano forming a new and entirely separate system.

(4) The work on the wells at Covolo was continued so as to deliver water directly into the 8-in. pipe-line from Pederobba running along the side of the Brentella Canal to the new filters at Biadene.

(5) In order to allow water to pass from one pipe-line to



NOTE. THE ENEMY LINE OCCUPIED THE NORTH BANK OF THE RIVER PIAVE. THE FRENCH OCCUPIED THE SOUTH BANK FROM FENNER TO CROCETTA, AND THE BRITISH FROM THENCE ONWARD TO NERVESA.

FIG. 1.

the other, the two supplies were cross-connected by a new pipe line between Covolo and Cornuda.

(6) The filters at Biadene were arranged in duplicate so as to allow one to be cleansed while the other was in use. There were two roughing filters followed by two sand filters composed of an 8-in. bottom layer of washed pebbles, 20 to 25 mm. in diameter, a 10-in. layer of washed pebbles, 20 to 15 mm. in diameter, an 18-in. layer of washed sand, passing a 3-mm. mesh. This filtering material was obtained from the river-beds. The filters were arranged for upward filtration and could be cleansed by reverse flow and treated with a strong solution of chloride of lime daily.

(7) In the branch mains supplying Montebelluna and Trevignano, the filtered water passed direct to the existing reservoir at Montebelluna where it was treated by drip-feed with chloride of lime.

(8) For the Biadene and Volpago-Selva main the filtered water was pumped direct to a contact storage tank on the Montello of a sufficient size to hold one hour's supply. The treated water was fed by gravity into the Biadene-Volpago systems, to which at the other end water from the spring at Giavera was added.

(9) In order to furnish a gravity supply to the trench system along the Piave river in front of the Montello, three reservoirs were constructed on the top of the hill to which water was pumped at the east end from the Giavera spring and at the west end from the filters at Biadene.

The cleansing of the filters and the treatment of the water with chloride of lime were under the supervision of the N.C.Os. of the sanitary sections.

When the area on a front immediately south of Asiago was taken over, provision was made to pump 8,500 gallons of water per hour to a height of 1,400 ft.; this supply was considered sufficient both for men and horses. Special 100-gallon collapsible tanks were purchased and experiments were made with water bags for carrying water on mules.

A memorandum on the preparation and use of hypochlorite of magnesia for the sterilization of water in small quantities was issued. This method of sterilization was considered to be specially useful in hill districts where water carriage in quantities was difficult. The hypochlorite of magnesia was made by macerating $\frac{1}{2}$ oz. of bleaching powder for one hour in 1 pint of water in a stoppered bottle; 1 oz. of crystallized sulphate of magnesia was then added, the mixture shaken and

allowed to deposit. The clear liquor contained approximately 0·5 per cent. of available chlorine. In the chlorination of water, one drop of the clear liquor added to one pint of water was considered to have the same sterilizing effect as half a scoopful of bleaching powder in a water-cart of 110-gallon capacity. The clear liquor was said to be stable and to have little alkaline reaction.

Certain experiments were also carried out in connection with the dechlorination of over-chlorinated water by means of hard-wood charcoal, fragments of which were packed in long cylinders between gauze supporting layers through which the over-chlorinated water was made to pass slowly, all "short-cuts" being avoided. The water was thus rendered much more palatable.

Owing to the water supply in the mountain area being insufficient, the allowance of water had to be limited to one gallon per man daily for all purposes. Divisions were asked to conserve water from melting snow, and to use it for washing purposes. The D.D.M.S. of the corps determined the amount of chlorination necessary in the case of the different pipe-line sources, and the necessary instructions were inserted in corps orders.

When the Province of Vicenza was taken over by the British troops, information concerning the water supplies, both civil and military, in the forward area was again distributed by the D.M.S. Copies of maps of the special military pipe-lines in the whole of the battle area to the east of Lake Garda were circulated. Geological maps of the British front area on the Asiago Plateau were also distributed.

On 12th July, 1918, in order to safeguard the quality of the water supply to troops in the forward area, the D.M.S. recommended the early installation of a Wallace-Tiernan chlorinator at each of the pumping stations for the purpose of chlorinating, either at the source or at intermediate pumping stations, all water which was being pumped forward by the three main pipe-lines. In order to permit of effective contact between the gas and water before the latter was delivered into the pipe-line system, the reservoir capacity at each pumping station was to be equal to the amount of water delivered after twenty minutes pumping.

On 12th August the Wallace-Tiernan gas chlorinator was installed on Mt. Costa at the intermediate pumping station on the Mortisa-Cavaletto pipe-line. The apparatus worked satisfactorily. A second Wallace-Tiernan gas chlorinator was

installed at Perpiana, near Campano, at the intermediate pumping station on the pipe-line which supplied the right sector.

At G.H.Q. schools and 2nd Echelon railheads the water supply was derived from wells and deep-seated springs. The wells were steined and fitted with copings. Chlorination was carried out where necessary, the majority of the wells requiring one measure of bleaching powder per 100 gallons. Notice boards were erected by the sanitary section stating the amount required.

On the lines of communication water was mainly obtained from the supply of the towns in which the units were located. The water was derived chiefly from ordinary wells, or surgent tubular and artesian wells. In most cases the water was stated by the Italian Public Health authorities to be potable, in others the water was regarded with suspicion. Samples were taken at frequent intervals and examined in the hygiene laboratories. Where necessary the water was either chlorinated or boiled, and waters containing excessive quantities of mineral matter were avoided.

The economic method of readily obtaining pure and abundant water supplies by means of deep tube or other wells driven into dry river courses or torrent-beds, particularly in localities where the bed formation consisted mainly of deposits of sand, water-worn pebbles or larger rocks, was also used. Reference has already been made to the water supply obtained from the shafts sunk in the bed of the Piave river at Covolo. They had been sunk in the front line during active operations. At Bordighera, on the lines of communication, the water supply was also derived from a series of deep wells sunk in the summer-dry river and torrent beds to the west of the town. The abundant water obtained by pumping from such wells from full or dry river-beds had the characters of a stored river water which had been subsequently subjected to slow sand filtration, the standard of natural bacteriological purity being exceedingly high.

The Director-General of the Italian Public Health Medical Service had placed duplicates of all archives at Rome, relating to water supplies throughout Italy, in the hands of his representatives at Italian General Headquarters; and much time and labour were saved by the close co-operation and assistance of these officers. The archives contained a complete survey and systematic record of the entire water resources of the country by communes and provinces. They proved of inestimable value to the British Expeditionary Force in Italy.

CHAPTER X.

WATER SUPPLY IN MACEDONIA.

THE town of Salonika was supplied with water from several sources, namely, the Hortiak aqueduct on the east, fed by springs from the top of Hortiak plateau ; the Eurendzik aqueduct, fed from old Turkish wells and springs above the village ; the Lembet aqueduct, arising in springs near Lembet village ; and a pump supply drawn from wells situated in the Vardar marsh.

With the arrival of the allied armies and the consequent influx of large bodies of men and horses these sources were quite inadequate, and the situation of many of the camps was such that the existing supplies were of little use and, therefore, other sources of supply had to be found.

The main concentration of the troops was in an area, the formation of which consisted of large deposits of alternating clays and sands for many hundreds of feet. Almost anywhere water was found in varying quantities in the sand strata, in some cases only a few feet from the surface, but occurring at varying intervals for some 700 ft., when bedrock was struck.

The quantities found in each bed varied considerably, ranging from a few gallons to several hundred gallons an hour. The average yield, however, was found to be about 1,000 gallons hourly.

In many cases springs were opened up, collecting pits constructed, and piped gravity supplies were brought down to the central distributing reservoirs. This, however, proved insufficient and had to be augmented by deep well supplies, of which upwards of 100 were sunk at the base and line of communication areas. In addition, shallow wells were dug with good results, and relieved the strain on the other sources.

In the base area the water supply was mainly obtained from :—

(1) Deep wells and Norton tube wells,
(2) Springs,
(3) Aqueducts,
(4) Shallow wells.

Generally speaking, the water supplies in the eastern section and town area were mainly aqueduct supplies, whilst in the western or Dudular area they were mainly deep well supplies. During 1917, the deep wells in the Dudular area were augmented

by the use of the Yenikoi Holy Well supply, a natural spring giving a daily yield of nearly 60,000 gallons, and the Dautbali springs, which collectively gave about the same amount, but this dropped considerably towards the end of each summer.

Seventy-eight wells were sunk in the base area. In one section of the base, at Karaburun, some 20 miles outside Salonika, twelve deep wells were bored, which furnished sufficient water to maintain two large general hospitals, two convalescent camps, one fresh air camp, and several R.E., Ordnance, and A.S.C. units, in an area which was otherwise entirely destitute of water. The average amount of water obtained was about 5,000 gallons per hour.

The selection of sites for deep wells required careful study. Geological records of the different strata were recorded in the daily drilling logs and the sections subsequently plotted. In this way each well drilled added to the information whereby possible results might be more accurately determined. With regard to the spacing of a group of wells and the area affected by them, the object was to space them so that while no two affected each other, there remained a minimum area intervening which would be undrained. The best spacing for such a group was to locate the wells in equilateral triangles, whose sides represented the diameters of independent circles drained by each individual well.

In some places it was found possible to obtain a good flow from Norton tube wells driven into beds of sand lying just below the clay surfaces and resting on another bed of clay, such beds being quite extensive in the flat country surrounded by hills. The yield from such wells was found to average 500 gallons an hour. In some cases the water-bearing strata were sufficiently productive to allow of a number of tubes being driven at varying distances apart and coupled to a main suction pipe. In this manner as much as 5,000 to 10,000 gallons an hour were obtained from a group of 15 to 20 tubes. This form of well tube had its limits and could only be relied on to a depth not exceeding about 23 ft.

The Yenikoi Holy Well supply consisted of a single spring in the rocks about 150 yards from the lower end of Yenikoi Gorge. This spring had been built round with the usual small shrine for offerings. Later, to protect the supply, the opening was concreted in by the Royal Engineers. The spring originally supplied an aqueduct, which led to a fountain in the village of Yenikoi, this aqueduct being carried along a rocky ledge to the entrance of the gorge, and afterwards by

means of earthenware pipes to the fountain. The aqueduct led off from a point only just below the water level at the door of the shrine. The R.E. pipe was inserted at a lower level giving about 1 ft. 6 in. permanent head of water at the source and was placed so that the supply for army purposes would not be affected by local waste. The village had also a supply from a catchpit at a quarry, at the entrance to the gorge, in itself sufficient for normal local needs.

The Dautbali catchpits were constructed during the summer of 1917 to meet increasing demands. The original source for this supply was a single locally built tank known as the "Market Garden Well." This was an erroneous description, as the tank was in effect fed by an aqueduct.

During the period of occupation of the area some horse troughs had been put up and a pipe led out of this tank to them, and early in 1917 a 4-in. pipe was led from the tank to three reservoirs placed above the camp of the remounts.

During the spring of 1917, ten catchpits were constructed in the village round points where springs used by villagers for washing purposes were flowing, and in the first week of June a catchpit was built and a pipe led from the broken aqueduct half-way between the Market Garden and the village to the Market Green catchpit. The ten village points were led by a special 3-in. main to the three reservoirs above the remount camp.

In the last week of June of the same year the Market Garden supply failed, and the other dropped considerably, but three more aqueduct pipes were traced and connected, and additional catchpits built at other water points in the village.

The Hortiak aqueduct supply to Kalamaria was one of the most important sources of water supply in Salonika Base area, and was conveyed by the ancient Hortiak aqueduct. This aqueduct runs from above Hortiak village to Salonika, its total length being about 12 miles. It is supplied by a number of large springs on Mount Kotos and Mount Hortiak, piped down to a small collecting chamber at the head of the aqueduct. On reaching Salonika the aqueduct throws out many branches, but no attempt was made to trace their ramifications. It supplied the prison in the citadel and many cisterns and public fountains in the higher part of the town.

The aqueduct was built of stone, with a stone slab cover, and ran for the greater part of its length about 6 in. below the surface of the ground. The gradient was not uniform. There were long, practically level, sections, followed by steep

descents. In cross-section the aqueduct varied according to gradient, being about 2 ft. by 1 ft. on level parts to 1 ft. 6 in. by 8 in. on slopes.

At two points only was there any difficulty in the construction of the aqueduct. First, a ravine had to be crossed, necessitating a bridge about 100 yds. long by 60 ft. high; and at another spot a ridge had to be cut through, causing an excavation of 25 ft. deep for about 200 yards. The aqueduct was probably of Roman origin.

The total yield of the springs varied from 21,000 gallons per hour to 16,000 gallons per hour, attaining the maximum during the months of May and June, and also with a maximum in October. At a meeting convened by the Commander-in-Chief of the allied armies, this source of supply was allocated roughly as follows: British, 50 per cent.; French, 12 per cent.; Italian, 9 per cent.; Greek, 29 per cent.

No work of any importance was carried out by the British on the aqueduct itself except the erection of two measuring chambers at the principal offtakes. These checked waste of water and detected leakage. It was discovered that between these chambers, which were about 7 miles apart, 2,000 gallons per hour were lost by leakage from the aqueduct itself. The cleaning of the aqueduct considerably decreased this loss. The Kalamaria group of hospitals received their water supply from this aqueduct by means of a 3-in. pipe-line, 41,500 ft. in length. The difference in level between the intake at the aqueduct and the discharge into reservoirs at the hospitals was 1,405 ft. Two break pressure tanks were established on the pipe-line, one at 14,000 ft. from and 500 ft. below the intake, the other at 17,500 ft. from it and 650 ft. below it.

Approximately 240,000 gallons daily were delivered to the hospitals from this source. The water was stored in a group of iron tanks of 19,000-gallon capacity. Additional storage capacity was required. This was obtained by constructing a reservoir of 40,000-gallon capacity on a small hill close to the hospital sites. Later, a second reservoir of 95,000 gallons was built alongside the first, which was then increased to 95,000-gallon capacity, giving a total storage of 190,000 gallons.

These reservoirs were excavated and banked round with the soil from the excavations. They were lined with puddled clay, covered with stone pitching, and roofed with light timber framing covered with old canvas. This covering was necessary to render the reservoirs mosquito-proof, and so prevent mosquitoes breeding in them. Deep wells were dug in 1916.

At first the water smelt and tasted of sulphur, but after a time this disappeared to a great extent.

The large aqueducts in the eastern area had no parallel on the other side of the town. There was, however, a network of small pipe aqueducts, probably laid down during the Genoese occupation, and this system consisted of a number of small pipes, usually one leading from each small crease in the hill-side. These had apparently been laid to points where a number of them fed a single pipe, which subsequently fed a fountain or store trough. Some use was made of these in connection with the piped system, but it was found that any attempts to put pressure on the earthenware pipes resulted in a burst at some higher point and a consequent wastage. These fountains were, however, useful in providing temporary watering places for passing troops by means of a lead-off from the stone tanks to temporary troughs and bathing places.

The shallow wells were purely surface drainage wells and were of two types :—

(*a*) A well, hand dug, of about 10 ft. diameter and from 15 ft. to 40 ft. deep, pumped by a hand-pump or mule-driven Bastier pump.

(*b*) A tube well, either singly pumped by the ordinary Norton tube attachment, or in series, connected to a large mechanical pump.

The first type gradually dropped out of use except for a group on the Monastir road.

The earlier scheme of distribution suffered from the inevitable difficulty of having to provide hurriedly for the immediate needs of particular camps and depôts without any preliminary comprehensive scheme. The result of this was that in most cases there was no alternative supply in case of a breakdown, and the amount available from different sources was not sufficient for the neighbouring camps.

During the winter of 1917 and spring of 1918 a comprehensive scheme was carried out in the Eastern area, by which every unit was provided with a rationed and certified drinking water supply, either directly laid on or delivered by cart from a near point. In nearly every case an alternative supply was made available by means of interconnecting valves and lines. Storage for half the daily supply of all water, other than drinking water, was provided in the various camps, so that the rationing of water by means of timed flow could be carried out; and efficient supplies were laid on to the two main ordnance and supply depôts for use in case of fire.

The net result was that a daily delivery of 258,000 gallons during the summer months was distributed in the Dudular-Uchantar district to some 8,000 men and 11,000 animals, on a daily ration averaging 5 gallons per man and 10 gallons per animal. This was in addition to a supply for the ordnance laundry and glycerine plant, and 10,000 gallons daily for railway engines, and for the Dudular baths and other services, without leading to shortage or other difficulty. All animals were watered according to time-table and all supplies were regulated by the Royal Engineers.

The areas occupied by the divisions were mainly in the mountains, and the divisions obtained their water supply almost entirely from springs, streams, and tube wells. On the lines of communication water was obtained from similar sources supplemented by a few deep wells. Fifteen deep wells were also drilled in the divisional areas and on the lines of communication.

All Turkish villages in Macedonia have channels of water running through them, or in their vicinity. These channels arise from springs, which are built round with masonry work, containing often a trough for watering animals and a place for standing receptacles. The small or medium-sized streams run over a gravel or sand bed and frequently disappear at intervals for a distance of several hundred yards. In such dry beds it was usually possible to obtain abundant water a few feet below the surface and in the divisional areas and on the lines of communication wells were sunk or dams built, and tanks installed in the beds or on the banks of such streams.

At Janes there was a small spring which yielded a natural aerated water. In Macedonia there were also many hot and sulphur springs, namely, at Loutra on the Salonika-Vasilika road to the east of the town, at Langaza and Pazaikia in the Besik lake district. At Pazaikia the water had a temperature of about 100° F. Baths existed at Loutra and Langaza, and were used by the troops. They were of ancient construction.

Most of the surface waters in Macedonia showed signs of marked contamination when examined at the Mobile Hygiene Laboratory. The deep wells sunk by the Royal Engineers provided in most cases a pure water and if properly protected required no chlorination. The aqueduct supplies were variable in quality, depending mainly on the condition of the aqueducts, the water at the source being generally pure.

As a rule all water supplies, except those from properly protected deep wells, were chlorinated.

CHAPTER XI.

WATER SUPPLY IN NORTH RUSSIA.

IN the occupied area of North Russia the three main sources of the water supply were the rivers, lakes and wells, the first of these being by far the most common. Generally speaking, the water was highly charged with finely divided particles of peat and had a colour closely resembling light ale.

With very few exceptions all towns and villages were situated on or near the banks of a river. During winter, when the river was ice-bound, the inhabitants selected a convenient spot on the ice through which to break a hole. The hole was kept open and served not only as the sole water supply for the village but also as the public washing place. Occasionally, however, separate holes were made for water supply and washing respectively. The area immediately surrounding this hole was usually a mass of frozen dirty water and refuse. The conditions were infinitely worse in the early summer when the thaw had commenced. The frozen accumulations of filth, manure and refuse in the village streets thawed and found their way by natural channels to the river, from the banks of which, now that the summer was commencing, the water for domestic use was obtained.

These were the conditions prevailing in nearly all the occupied villages.

In a few towns, such as Murmansk and Onega, well water in addition to river water was available. Where this was the case an outcrop of sandy soil existed in which wells of the shallow variety had been sunk. These, however, were invariably contaminated by surface water and foreign bodies. The well-boring was steined with thick log planks. No arrangement other than ineffective wooden covers, not unlike small huts, was provided to prevent surface contamination.

The methods of supplying water to such towns as Archangel, Solombola and Bakharitza were less crude. Indeed, in Archangel a real effort had been made to supply purified water to the town from the River Dvina. The waterworks were situated in the southern portion of the town and the intake pipe had its distal end mid-stream in the river. This portion of the river had been specially selected, since it was not used for

mooring ships and was undoubtedly less subjected to contamination than other portions.

Water was laid on to many houses in the better-class portions of the towns and to public buildings and institutions, and in this way, approximately 700 of the 2,000 buildings in Archangel were supplied with water. The service pipes to the houses were of galvanized iron, as lead pipes were dangerous on account of the peaty and therefore "soft" nature of the water, and, as a precaution against freezing, the pipes were run through a box about 1 metre cube filled with sawdust and placed at the ground floor of the house. Apparently very few cases of frozen pipes occurred.

For the remaining portions of the town, water-houses were established. These were usually to be found at the junction of four streets. Here the supply pipe was covered by a small hut, the interior of which was warmed to prevent freezing in the supply pipe. The inhabitants came for their daily supplies which they carried home either in barrels mounted on sleighs or on wheels, according to the season, or in buckets. In the great majority of the houses, both in towns and villages, water was stored in large wooden butts which usually occupied a corner of the kitchen.

The local authority at Archangel, however, did not consider it necessary to chlorinate the town's supply during the cold months, and this operation was consequently suspended from 1st October until 30th April, although sedimentation and filtration were allowed to continue. Apparently, three years previous to the allied occupation of Archangel the authorities there had arranged for bacteriological examination of the unchlorinated water. As the results of the examination were believed to show the absence of harmful organisms, the Russian authorities discontinued the addition of chlorine. The British, however, were not satisfied with these arrangements, and after the Adviser in Pathology had demonstrated the presence of *B. coli* in less than 0·5 c.c. of a sample taken from a tap early in December 1918 representation was made by the D.A.D.M.S. (Sanitation), who appeared in person at a meeting of the Town Council with a view to arranging for the maintenance of chlorination through the whole year. After the Russian Medical Officer of Health had examined the bacteriological methods of the British, arrangements were made, with British assistance, to re-establish chlorination during winter. Thus the supply to Archangel was rendered safe for consumption by all. Regular inspection of the waterworks by men of No. 125

Sanitary Section was undertaken, particular attention being paid to the methods of adding the bleaching powder both in regard to quantity and the quality required.

At Solombola, with a population of 26,000, the picture was very different. It was entirely without a domestic water supply, although a good one was projected and, but for the war, would then have been under construction. Here the arrangements were of the crudest, although admittedly an attempt had been made to purify by chlorination. Dvina river water was used but, unlike Archangel, the same care had not been taken in the selection of the intake site. The intake pipe ran out from the river bank for 8 ft. to a part of the river which was used almost entirely for the mooring of ships. Storage tanks under cover of a substantial warm building were situated in the market square some hundred yards from the river. An engine pumped the water to a large cylindrical tank in the upper part of the building. The tank had a capacity of about 800 gallons and was filled and emptied about seven or eight times in a day. Sedimentation and filtration did not form part of the purification arrangements. Chlorination had long since ceased, although at one time apparently it was the duty of the engineer in charge to add daily through a small funnel-shaped attachment an unestimated quantity of bleaching powder at each filling of the tank. This was Solombola's only supply. The water at times was of a pea-soup consistency. The inhabitants arrived at the tank-house with their water-carts or sleighs to receive their daily supplies. A special arrangement existed, however, by which the large naval barracks and the military hospital about 200 yards distant received their water supply by a 2-in. pipe from the pumping station.

Solombola gave accommodation to a comparatively small number of British troops. It was impossible, on account of the confined accommodation in which the supply tank was situated, to arrange for central purification. Attention had, therefore, to be concentrated upon the needs of individual billets, of which, to increase the difficulties, there was a large number. In such circumstances the water clarifier (Horrocks' pattern) proved invaluable. As far as possible, each billet was provided with one apparatus. Men of the sanitary section made frequent and regular visits to the billets to ensure, not only that its use was being maintained, but that the results were effective. Estimates were invariably carried out by means of the water sterilization test case.

A few service water-carts, part of the establishment of

certain units, were available and were brought into use, and to prevent freezing, wooden structures containing stoves were built round them. Outside the base, however, they were not used. The length of the lines of communication, the comparative dearth of inland water transport, and the fact that sleigh transport could not readily cope with such heavy material, precluded water carts from going forward with the troops.

No. 85 General Hospital, early in October 1918, had taken over a large building in Solombola, which was in course of erection. Advantage was taken of the opportunity to adapt the building to the needs of a modern hospital, and in this way plans were drafted for the inclusion in the building of a special purifying plant for hospital water supply. The system consisted of a control tank and a supply tank, with a series of four sedimenting tanks interposed between. A ball valve regulated the water level in the control tank. Situated over the sedimenting tanks were two shallow receptacles, one for the alum and soda solution, communicating by a pipe with the control tank, and the other for the bleaching powder solution communicating similarly with the supply tank. The average rate of flow to the control tank from the pump had been calculated by meter, and, after the water had been tested for its chlorine and alum requirements, the appropriate taps of the reagent solution chambers were set so as to drip into the respective tanks at a rate sufficient to give half a pint in the time that half a pint of each solution had been calculated as necessary for the incoming water. The chlorine solution, before reaching the supply tank, was forced to run through a baffled trough to ensure mixing. The apparatus worked all day filling the tanks, whose contents were available for use the following morning. An orderly was trained in the duties and detailed to manage them. The flow of water was gauged, and the supply of chlorine estimated several times daily. The work was completed in May 1919, in anticipation of the thaw, and worked well.

At Bakharitza, the arrangements for the supply of water were intended primarily for the sole purpose of fighting fires. Here, too, the source was the River Dvina. The water was pumped from mid-stream to large tanks, which were situated in one of the fire stations, whence by gravitation in a pipe system the water reached various parts of the docks. These water points—four in number—were not unlike those in certain parts of Archangel. The supply taps were covered by small buildings, in which warmth was maintained by stoves. Little

sedimentation occurred; indeed, only as much as resulted during the night when little, if any, water was drawn. No arrangements for purification existed. Here again service water-carts were brought into use and warmed protective buildings erected over them. The number of troops billeted at Bakharitza was at no time large. However, it was an important centre, since it served both as the port of disembarkation and base, not only for the railway line of communication, but also for the river and sleigh routes. Royal Army Ordnance Corps and Royal Army Service Corps depôts and railway troops were also established there.

At first, throughout the force, all troops were required to boil water until such time as arrangements could be made for adequate purification. Whilst this step undoubtedly prevented to a large extent epidemics of infective intestinal diseases, diarrhoea, apparently of a non-infectious nature, was not uncommon, and there seemed little doubt that its occurrence was due to the mechanical irritation caused by the large amount of suspended matter in the river waters. Cases of diarrhœa were observed not long after the arrival of the troops in Archangel, but later the epidemic character passed off, due, it was believed, to a tolerance subsequently acquired.

Subsequently, but unfortunately not for several months, satisfactory arrangements were made for the troops in the forward areas and on the lines of communication, when material and labour became available at the base. The "vodka" drum was adapted to act not only as a receptacle for the storage of purified water, but as an apparatus in which sedimentation and chlorination were also carried out. "Vodka" drums held approximately 100 gallons of water and were prepared in the following way. The top having been cut out, a wooden cover was substituted and made to fit closely. At the junction of the lower and middle third, a stopcock was inserted from which to draw the prepared water; whilst at the bottom a plug was fitted to facilitate the removal of the sedimented solids. By means of the test case, the amount of bleaching powder to be added to a drum of water was estimated, and this quantity was mixed with clarifying powder and a small proportion of water to form an emulsion. The whole was poured into the filled drum and stirred with a clean stick. At the end of four hours sedimentation was completed and sterilization effected, so that a safe supply could then be obtained from the upper draw-off tap. These tanks were usually set up in pairs to ensure a constant supply of potable water, one tank

being in use whilst the other was sedimenting and chlorinating. As far as possible sets were supplied to troops in the forward areas.

More elaborate arrangements were made for railheads, barges and troops in large concentration. Three tanks were made, either a 100-gallon and two 50-gallon "vodka" drums, or three wooden tanks lined with zinc or canvas. These were constructed by Russian carpenters. The large tanks for the crude water were treated with alum and soda to facilitate sedimentation. A minimum period of four hours was allowed for the completion of the action. The deposit was removed through a plug-hole in the bottom. A pipe was taken from this tank at the lowest clear-water level and led to each of the two smaller tanks. The entrance of the clear water into the small tanks was controlled by taps. The amount of bleaching powder required to sterilize the clear water in each of the small tanks was estimated and applied, after mixing it with a small quantity of water, through funnel-shaped orifices in the tops of the tanks. Another four hours elapsed before consumption by troops was permitted. By this method a continuous supply of sterile water could be obtained. Clarification was taking place in the large tank whilst alternately the small tanks were chlorinating or distributing.

For small posts, oil drums were adapted for the supply of chlorinated water and chlorination was carried out in a manner resembling generally that described above. The application of the chlorination test case to the various water supplies in North Russia gave the following average reactions :—

River and lake water—	
Clear though yellowish	4 grammes per 100 gallons.
Turbid	6 ,, ,, ,,
Well water—	
Clear and bright ..	2 grammes ,, ,,
Yellow or turbid ..	4 ,, ,, ,,

Clear descriptions and illustrated instructions for all these modifications of the usual methods of purification were circulated amongst the troops, so that every assistance was given to units and detachments to ensure the use of clarified and sterilized water for drinking and even cooking purposes.

In many cases, however, sufficient attention was not given to this as to other sanitary matters, due partly to the difficult conditions under which both officers and men had to work, and partly to the lack of sufficient number of skilled sanitary personnel. In addition, the British troops, and particularly

those in the forward area, were split up into a large number of detachments of varying sizes, in most cases disposed widely apart one from another. Frequent and regular inspection by members of sanitary sections would have involved, in view of the great distances between occupied villages, the employment of a number of skilled sanitary personnel in a proportion much greater than that found necessary in an area of smaller size in another theatre of war.

CHAPTER XII.

DISPOSAL OF WASTE PRODUCTS.

THE history of the war of 1914–18 fully demonstrated the well-known fact that practical sanitation in the field differs fundamentally from that of civilian life. Sanitary appliances in the former have been determined more by local conditions and available material than by any theoretical considerations of construction.

The diversity of conditions under which the work had to be carried out rendered standardization extremely difficult and, as a result, full play was given during the war to improvisation; a plethora of designs and modifications resulted, from which at first sight it was difficult to make any satisfactory selection. In the vast majority of instances, however, the inventions merely represented the modification of some fundamental type to suit a special requirement or, at times, to satisfy a desire for originality. Many such modifications either served no useful purpose or introduced unnecessary complications and could be disregarded; others, though not affecting the main principle, were of undoubted value.

The appliances used on the various fronts corresponded very closely as far as general principles were concerned, but were modified to meet the local conditions and available material. Sanitation in the Eastern theatres of war was very much the same as on the Western fronts.

Conservancy may be said to include all matters dealing with the disposal of solid and liquid excreta and of solid and liquid refuse.

In military life, where a proper drainage system is installed, the disposal of excreta presents comparatively few difficulties and corresponds closely with any ordinary municipal disposal scheme. Camp sewage, however, is richer in organic material than town sewage and frequently contains an excess of fat, and these facts had to be remembered in disposing of waste material from camps.

In certain home camps during the war the solid excrement was burnt and the liquids were dealt with by means of drains and by a system of surface irrigation. This was a satisfactory method of disposal provided that enough land was available, at least one acre per 1,000 troops, at a sufficient distance from the camp not to cause a nuisance in hot weather.

The disposal of solid excrement in a camp without a proper drainage system always proved difficult, but much work was done during the war to solve the difficulty.

Fæcal material could be buried or it could be burned. It might be buried *in situ*, as in the case of the "shallow trench" and "deep pit" latrines, or it might be removed to a distance and buried, either by "digging in" for agricultural purposes or in trenches or deep pits. On the other hand, it might be burned in some special form of incinerator. All these methods were extensively employed during the war and there can be little doubt that for general work in base camps, on lines of communication and in rest areas the most satisfactory system proved to be fly-proof receptacle latrines and a scheme of incineration with a properly trained personnel in charge of the work. For front line areas some burial system was generally adopted, preferably the deep pit latrine with fly-proof, self-closing covers. The shallow trench or straddle latrine proved a failure owing to the difficulty of management under conditions of stress and the disastrous result of wet weather upon any such system, as well as owing to the extensive areas of ground which had to be used in a system of shallow trenches, when troops were in camp or bivouac for prolonged periods. This was one of the chief reasons why the shallow trench system had to be abandoned soon after trench warfare had been established on the Western front. It was, however, necessary to adopt this form of latrine under conditions of mobile warfare. It was then essential that attention should be paid to the details of construction and management laid down in the manual of field sanitation and field service regulations, more especially with regard to covering with earth in order to prevent flies having access to infective material.

Flies constituted the chief argument against the shallow latrine. In using deep pit latrines water contamination was the chief danger, but at times the deep pits also proved fertile centres for fly breeding.

There was very little to recommend the removal and burial at a distance except in the case of receptacle latrines used in the trenches. Certain home camps, as well as a few in Italy and Alexandria, had the bucket contents removed by contractors, generally for agricultural purposes. Such a system, however, had little practical value from a military point of view. The closest supervision was necessary to see that the contract was properly carried out, and frequently material thus removed was allowed to accumulate near the camps, or

leaking conservancy carts spread a trail of filth and flies across the camp.

Occasionally the local health authority undertook the contract and, as the whole process was then under the supervision of trained sanitary inspectors, it was carried out in a satisfactory manner.

The best system was perhaps that of receptacle latrines and destruction in a closed incinerator, but where this could not be carried out deep pit latrines with fly-proof covers were generally employed. The use of receptacle latrines and subsequent burial and of shallow trench latrines was generally abandoned as the war progressed.

The war, however, provided exceptional opportunities for experimenting with all systems, and a review of the war experience of each is consequently of much interest and value.

Receptacle Latrines and Destruction in a Closed Incinerator.

This system of dealing with solid excreta was extensively utilized in home camps and on every front. When properly carried out, it greatly diminished the chances of fly infection and was a rapid method of disposing of potentially dangerous material. It also did away with any risk of contaminating the water supply. On the other hand, the material for erecting incinerators might be difficult to obtain, and fuel was generally required in addition to ordinary camp refuse. A trained personnel was also essential. For home camps, base camps, rest camps and lines of communication, the advantages outweighed the disadvantages, and the cost was materially reduced by improvisation. Personnel was obtained from amongst men unfit for duty in the front line, and strict rules were enforced with regard to cleanliness and clothing. In the front line, incinerators drew enemy fire and their use was not permissible near the trenches.

Near the front line also personnel was a difficulty. Many of the men most suitable for incinerator work were the men who had suffered from shell shock. They made excellent sanitary personnel in suitable surroundings, but were unsuitable for work in the front line. When men fit for duty in the trenches were employed, they were liable to be taken away to meet some pressing emergency at a time when they could least be spared.

As a rule care was exercised in the selection of sites for sanitary areas; occasionally, the latrines were too near the cook-houses, and incinerators were sometimes placed where

they gave rise to nuisance, but more often the error was in the other direction, and latrines were situated at too great a distance from the camp, with the inevitable result that fouling took place in the neighbourhood of the camp. Frequently, too, latrines constructed in the summer months had no suitable approach, and in consequence became unusable in bad weather.

It was found necessary, wherever possible, to provide some form of head shelter to receptacle latrines ; otherwise the seats became wet, and in bad weather the user preferred to squat rather than to sit upon the seat. Tarred felt or canvas afforded a certain amount of protection where more permanent material was not forthcoming.

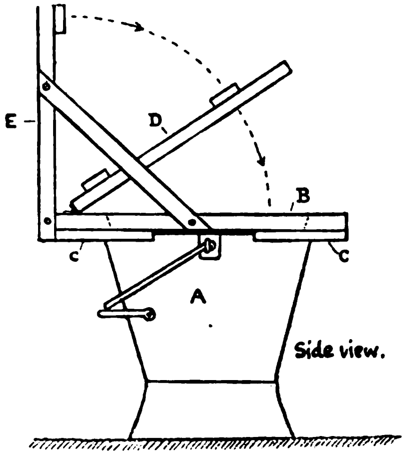


Fig. 1.—Diagram of wooden fly-proof seat fitting directly on to bucket. A—Latrine bucket. B—Seat. C—Cleats to ensure proper position. D—Fly-proof cover with cross pieces to prevent warping. E—Back standard causing cover to close automatically.

Where it was possible to provide an impermeable floor it became necessary to drain it to a covered soak pit with punch bowl depression. Cases occurred where a carefully prepared concrete stand was constructed without any gutter or drain, with the result that the foul washings simply ran off the platform and polluted the surrounding ground.

The seat, as already noted, had a fly-proof, self-closing cover, and was made to fit as closely as possible to the upper edge of the bucket.

Stops fixed to the floor were necessary in order to ensure a proper position for the receptacle, but this important detail was often overlooked.

A cover fitting accurately on to the upper rim of the bucket proved satisfactory and had many advantages, but it was more common to use a box with a self-closing lid, though in these cases there was considerable danger of the woodwork becoming fouled.

Fig. 1 shows a simple type of cover for fitting directly on to a latrine bucket. The support at the back safeguards the hinges, which too often are a point of weakness; many latrine seats proved failures owing to an attempt to produce automatic closure by small wedge-shaped stops, which merely acted as a fulcrum for enabling the weight of the body to exert its maximum effect upon the hinge.

The chief objection to this type of seat was that the user felt somewhat insecure. This was easily remedied by carrying the back support down to the ground. A cover of this kind precluded any chance of fouling the ground in front. The design was used with success in various Eastern war areas.

Many other patterns of seat, which fit directly on to the receptacle, were used during the war.

The shape of the seat was important. With a round hole there was always the liability to foul the woodwork at back and front; lateral supports were quite sufficient for all practical purposes. On the Western front a form of seat with side supports only was found to be very suitable; in the East, however, with innumerable flies seeking access to the latrine, it was not advisable to have any holes or cracks, even during the period of use, and it was considered better, therefore, to adopt an oval shape. There was also every inducement to reduce the area of contact to a minimum, more especially in consequence of possible infection by scabies.

In some of the large camps in the United Kingdom the need for economy in material led to the construction of less effective types. In very few of the camps was the fly-proof cover used, and frequently the back portion of the seat was removed, so that the user was thrown into an uncomfortable position, and was apt to foul the ground in front of the receptacle.

Where the receptacles were washed at the latrine, as was sometimes done in camps in the United Kingdom, it was necessary to provide a stand-pipe and cemented trough, with a drain leading to a properly constructed closed soakage pit.

As the solids had subsequently to be incinerated, the attempt to separate liquids from solids in the receptacles led to many devices being employed. Several types of double receptacle

were designed. A method that was commonly adopted was to decant through a sieve or strainer, leaving only the more or less solid residue for incineration. The various methods of separation which were utilized in the field are described below.

The incinerators were placed as close as possible to the latrines and on an impermeable floor. In most cases they were covered by a roof.

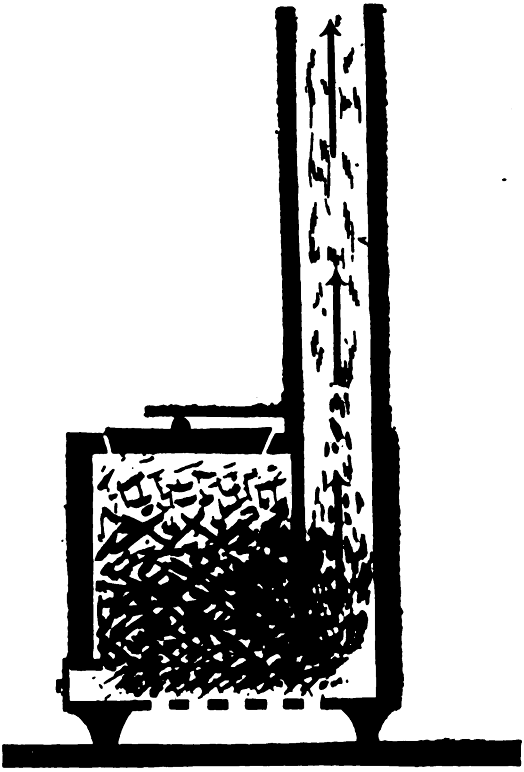


Fig. 2.—Showing principle of Horsfall destructor.

When dry refuse was used for mixing at the incinerators with the contents of latrines, a cement mixing slab was necessary with proper drainage to a covered soak pit. Places had also to be provided where the personnel could wash and change their clothes. Store-rooms for fuel and the other articles also formed part of the organization of an incinerator centre. These requirements, as well as others connected with the management of incinerators, were gradually recognized during the war.

Many patterns of closed incinerators were used. The essential feature of all such incinerators was the possession of a baffle plate, so placed that all fumes were driven through the hottest part of the incinerator, or combustion chamber, before passing up the chimney. Certain other patterns, such as the "closed beehive" or "Sialkote" pattern, were advocated, but for general purposes at home reliance was placed on the reverberatory principle, which was the basis of the patented incinerators such as the Horsfall, supplied to many of the camps at home.

This incinerator was also used in some theatres of war. Occasionally, its full value was not obtained owing to neglect of certain essentials, more especially with regard to the provision of a shelter and skilled personnel, and it was wasteful to use an expensive Horsfall incinerator for burning ordinary dry camp refuse.

Fig. 3.—Bailleul incinerator.

The so-called "Bailleul" incinerator (Fig. 3) was founded upon the general design of the Horsfall. It was devised by Major Smales, O.C. No. 4 Sanitary Section, to overcome the great difficulty experienced in some parts of the French front with regard to material. It was constructed from waste tins, filled with clay and clinker, and wired together.

The Bailleul incinerator, like the Horsfall, had a hanging bridge, or baffle plate; it was practically an improvised Horsfall which might be made from any available material.

At first this incinerator had a "top feed" door, but it was found that this improvised metal door quickly buckled and became useless. To meet this difficulty, the top door was

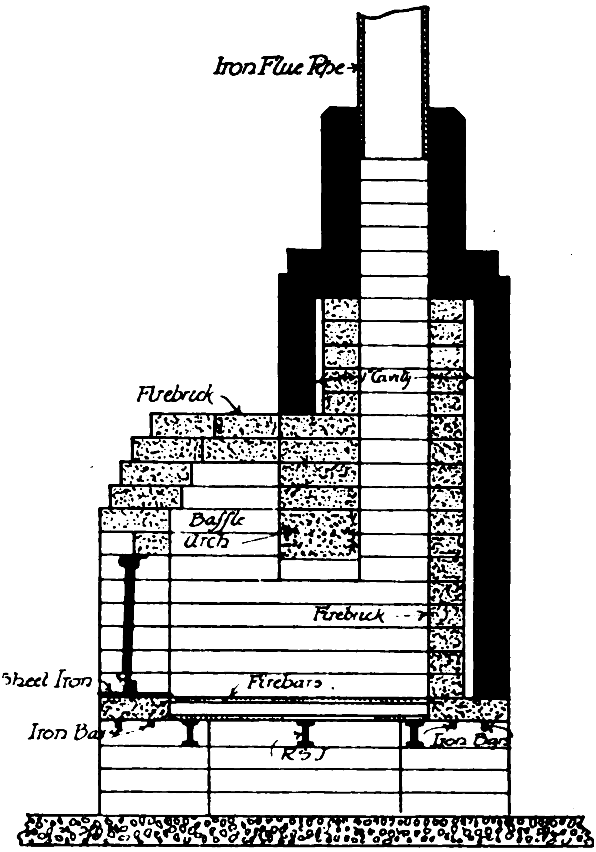


Fig. 4.—Front feed brick Bailleul incinerator (longitudinal section).

abolished. Its place was taken by a hot-water tank, or it was bricked over, and the incinerator was fed from the front only. As this encouraged careful stoking, the apparatus worked well.

An air space was also introduced between the outer bricks and the fire-brick lining, with great advantage to the structural

security of the apparatus. As in the case of the Horsfall, some form of shelter was required.

These incinerators required careful handling, especially in order to avoid damage to the hanging bridge of fire brick when stoking. Very high temperatures were generated, and the fire-bricks had to be renewed from time to time. As in the Horsfall, the best results were obtained by sloping the refuse downwards towards the back of the incinerator and leaving the four corners clear so that they could act as draught channels. Black smoke was an indication of the necessity of admitting more air through the charging and raking doors.

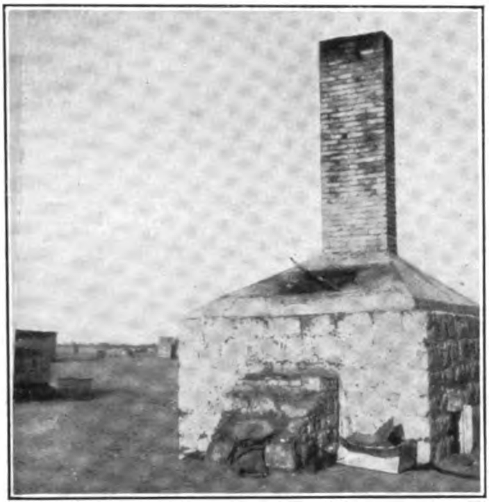


Fig. 5.—Large closed incinerator, Egypt.

It was found that such an improvised apparatus would work successfully for six months, and, if lined with fire-brick, for eighteen months. Subsequently, this incinerator was adopted as a standard pattern for camps in England, constructed either from bricks or tins, with a lining of fire-bricks. It was found that the ordinary type of Horsfall and the full-sized Bailleul incinerator could deal with the excreta and refuse from 1,000 to 1,200 men in twenty-four hours, and in an emergency even larger quantities could be consumed.

Incinerators of a similar pattern modified to suit local requirements were used in France, Egypt, Mesopotamia,

Palestine and Salonika. Types of these are illustrated in the following drawings.

Fig. 6.—Double-chambered closed incinerator, Salonika.

Fig. 7.—Large closed incinerator, Mesopotamia.

In certain of the very extensive home camps the Meldrum destructor, capable of dealing with the refuse and excreta of 6,000 men, was used. This destructor depends for its action upon a forced draught, produced by a steam jet. It is effective if properly used, but needs considerable care for

successful and continuous work. The fumes are cremated by passing through a combustion chamber, which separates the furnace from the flue.

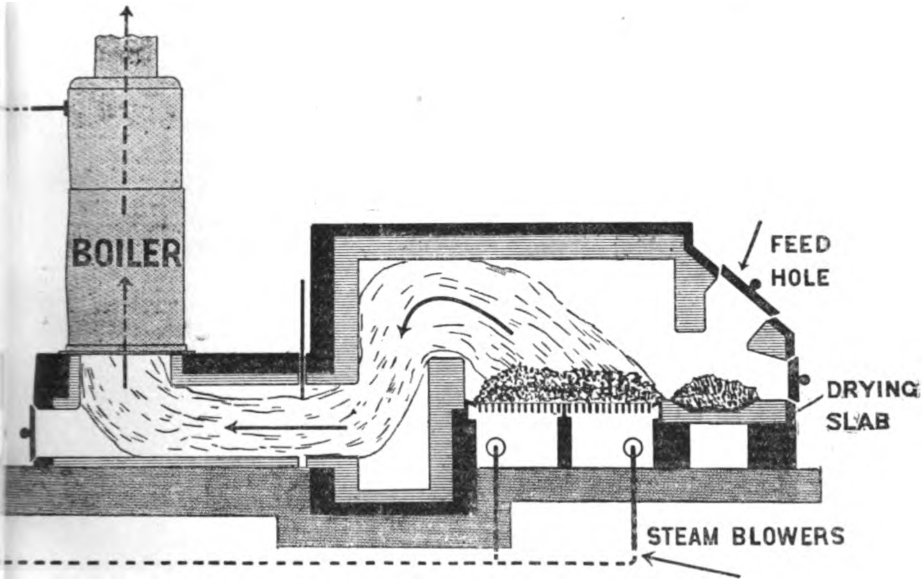


Fig. 8.—Meldrum destructor.

Two types of the Meldrum destructor were used in home camps during the war. A small type, shown in Fig. 8, was fed through a hopper at one end on to a drying slab, whence the material for incineration was raked on to the fire. A large type, which could deal with the fæcal matter of an additional 1,500 to 2,000 men, was fed from a platform at the top, the material passing directly on to the fire.

For some time these destructors were wrongly used, but in competent hands they ultimately proved successful. The chief objection was that the refuse and fæcal matter had to be collected from a considerable area with the consequent difficulties of organization and carriage. As a rule, it proved more convenient to install unit destructors dealing with the refuse of one battalion only.

Wherever possible, closed incinerators should be lined with fire-brick. It was a common mistake to ignore the fact that there is no comparison between the heat to which an open incinerator is exposed and that which is generated in a closed incinerator, with the result that closed incinerators, upon

which much time and trouble had been expended, cracked and became useless in a very short time.

Certain other forms of incinerator which proved of value for burning excreta may be mentioned.

One type was the incinerator with drying shelf or drying grid as shown in Fig. 9. It had its good points. If all fresh material had to fall on the grid or shelf, it was difficult for a careless stoker to overload the machine and put out the fire. Also when dry refuse was scarce, it was distinctly advantageous to dry the material before it fell into the fire. On various fronts incinerators of this type were constructed, some with one grid, others with two or even more, and many of them worked for long periods with success.

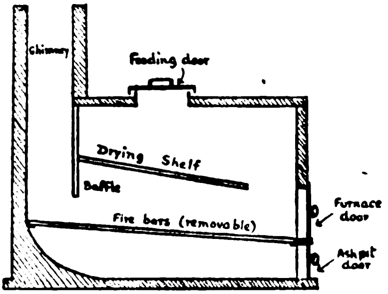


Fig. 9.—Incinerator with drying shelf.

The chief objection to them was that the drying shelf very quickly burnt through and owing to expansion was liable to " thrust out " the walls of the incinerator. To overcome this defect, the grid had to be made loose, so as to allow of expansion and easy replacement. Later experience showed the value of movable bars, not only for the drying grid but also for the bottom of the furnace.

Incinerators, in fact, which were constantly used, required much attention and repair, and it was essential to guard against their being out of action for long periods.

The Sialkote type (Fig. 10) was practically a large, closed " beehive " incinerator. It was easy to construct and very strong ; it could burn an enormous quantity of refuse in the day and was easy to manage. The chief objection lay in the fact that fumes and smoke were not destroyed. This objection was overcome to a certain extent when the furnace was at full heat, but the type was on the whole inferior to the reverberatory type of incinerator except in an area where

noxious fumes did not matter. It was, however, extensively and successfully used during the war.

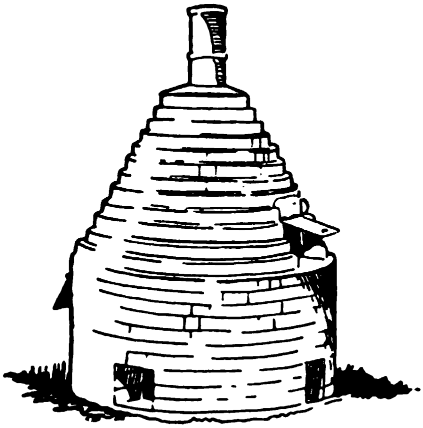


Fig. 10.—Beehive incinerator (closed type).

The shape guaranteed stability, and incinerators of this type were found less liable to crack than the closed patterns which were square-shaped. The Sialkote type proved specially useful for ordinary camp refuse as the ashes were not liable to be blown about.

The Trinca incinerator is an interesting modification of the drying grid type. The following is a description of it.

This incinerator is built on the beehive pattern and has as its main principles a subterranean air space for draught, a central air cone, and at the level of the top of air cone, and close to it, a perforated tray for burning fæces. The walls are made of brick, stones or similar material cemented together with a mixture of clay five parts and cow manure one part, the addition of the latter making the mixture very binding, and to some extent limiting cracking by heat. Having the air space below ground saves a large amount of building material that in most incinerators is used up to construct the walls surrounding the air space above ground.

The subterranean air space gives just as good a draught as any other and with an open air cone above its centre produces a draught when inflammable material, such as wood or paper, is being burnt, almost as great as in a blast furnace. A zone of intense heat is produced immediately around the air cone on which rests the fæces tray. The fæces are rapidly dehydrated and charred and ultimately catch fire. The perforations in the tray allow cresol, urine and liquid fæces to percolate through on to the bed of manure and fuel beneath, which absorbs them. In the zone above the air cone, gases and smoke arising from the burning and destructive distillation of contents are burnt, and what escapes from the funnel is practically only steam, and soon is dissipated into the surrounding atmosphere, so that the incinerator is not one that reveals its presence through smoke.

The first model built was a small one with an inside diameter of 4 ft. 6 in. at the base and in height. It was only built as an experiment to test the heat and draught produced but it was found afterwards to be sufficiently large

to cope successfully with all the ordinary refuse, dressings and fæces from a field ambulance, together with the manure from 56 horses.

The only disadvantage was that the fæces tray was somewhat small and necessitated three separate burnings to destroy the fæces of the field ambulance personnel and a daily average of 18 patients.

Some attention and common sense are required to work this incinerator properly. The procedure is as follows: A layer of the more combustible refuse such as papers and dressings is introduced through a door, then old jam tins and on the top of them manure. The fæces are poured in through special shoots and evenly distributed over the tray after the refuse has been ignited and is burning freely. If there be sufficient refuse and manure the incinerator can be kept burning indefinitely, and is always ready to receive fæces or soiled dressings. A cylinder to hold water can be built in alongside the funnel to give a constant supply of boiling water.

Although the burning of solid excrement in an open incinerator was not theoretically satisfactory, it was carried out with success in all theatres of war. In one unit an ordinary "beehive" with a double grid was used (Fig. 11). All the refuse and excreta of the unit were dealt with and very little nuisance arose. In this case a large supply of combustible refuse, such as saw-dust and shavings, was available.

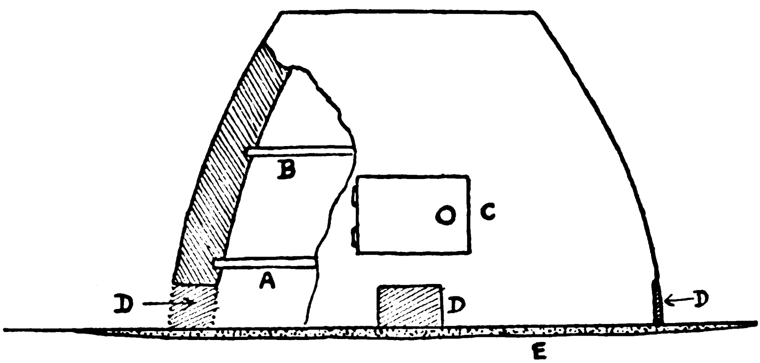


Fig. 11.—Double-grid beehive incinerator. A—Lower grid for incineration. B—Upper grid for drying. C—Stoking door. D—Draught holes. E—Cement base.

The above descriptions are of standard types of latrines and incinerators, such as the experience of the war brought to prominent notice, but several modifications were introduced. It became obvious that any system which provided for immediate incineration by the individual himself approximated very closely to an ideal, as thereby danger of infection was immediately removed, there was no handling of excreta by a sanitary personnel and there was no risk of accumulation in receptacles.

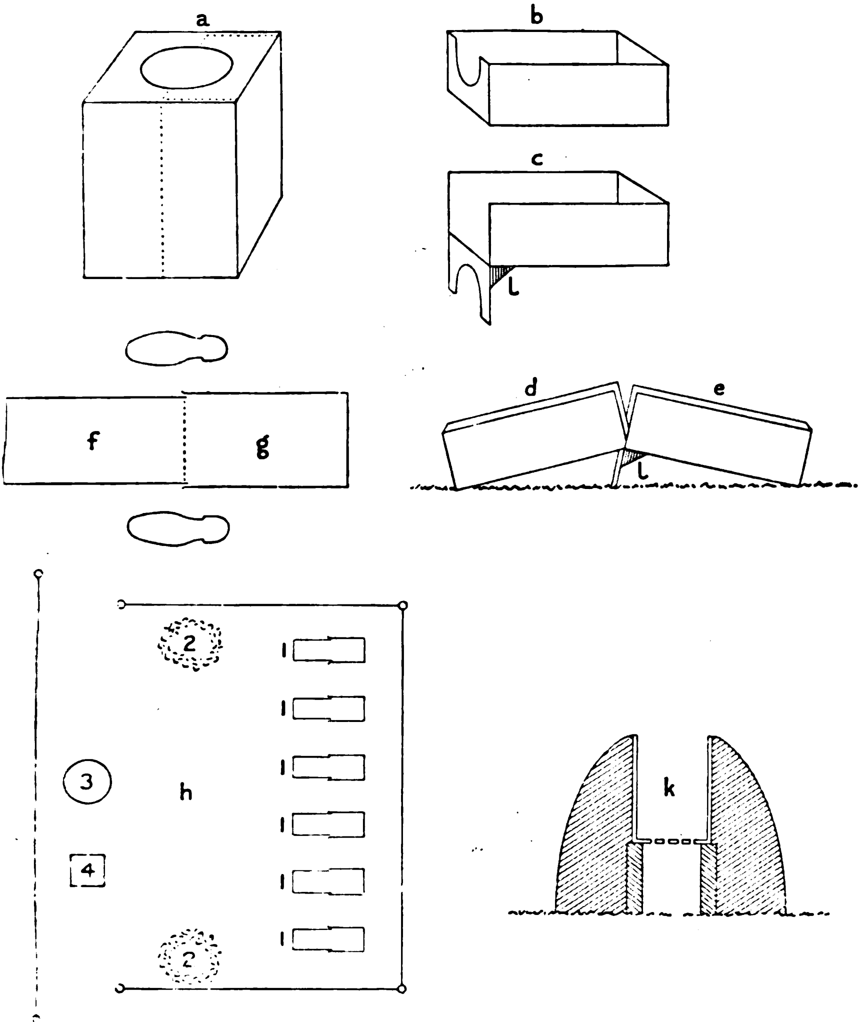


Fig. 12.—System of latrines of biscuit tins for incineration of excreta. a—Biscuit tin cut along dotted lines. b and c—The two trays thus formed. d and e—Method of placing the trays on the ground, as latrine receptacles. f and g—Plan of trays placed as latrine receptacles with position of feet a-straddle. In tray " g " a bed of straw, paper or other dry combustible material. l—Triangular piece of tin soldered on to tray to strengthen foot piece. h—Plan of a latrine screened enclosure: 1—Trays in position; 2—Heaps of straw or other material for placing in trays as at " g "; 3—An incinerator as " k "; 4—A urine absorption pit or receptacle. k—An incinerator of empty paraffin drum with perforated bottom, standing on bricks, and built in with puddled clay.

The D.M.S. of the First Army, Surg.-General W. G. Macpherson, devised a latrine in 1915 to meet these requirements, but chiefly in order to replace the shallow trench system, which was leading to extensive areas of foul ground. Two improvised receptacles placed at the ground level received the excrement, which was immediately incinerated in an adjacent furnace by the user himself, the liquid being poured into a covered urine pit. Such a system is theoretically perfect and worked with success in units where it was well understood and controlled. Where many used the latrine constantly no fuel was necessary, as it was found that the fæcal matter itself was the best fuel. The chief difficulty was the personal factor, but the system was carried out successfully at a casualty clearing station of the First Army, where its advantages were fully realized, even during the stress of work resulting from heavy fighting. In fact, many of the medical units of the First Army and Salonika force used this system of latrines, the casualty clearing station referred to above having employed it continuously throughout the war (Fig. 12).

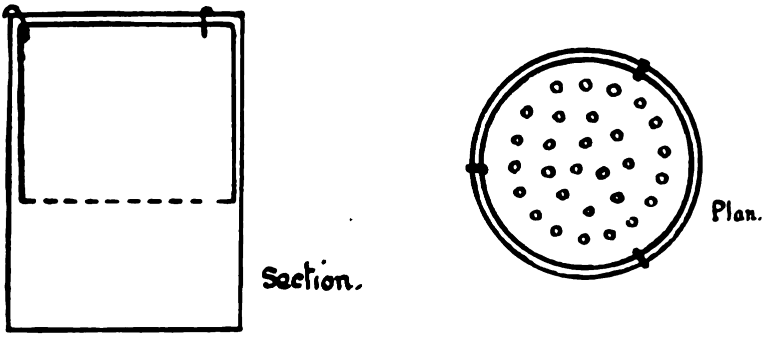


Fig. 13.—Improvised latrine bucket and urine separator. A metal oil drum as receptacle ; separator made from smaller drum and bottom perforated. Separation not so satisfactory as in other methods because liquid motions pass through perforations.

A modification of this system was used with success in small selected units (Fig. 13). The receptacle consisted of a perforated tin fixed into a larger tin. In the upper, a layer of hay or straw was placed to receive the solid excrement ; this was emptied into the incinerator after the urine had drained through into the lower receptacle.

A small incinerator, made from a cresol drum, was used for burning the material, and a model closed urine pit was placed in close proximity to it.

These individual incinerators did not come into general use, but they represented an effort to attain an ideal, and as such are extremely important.

Many ingenious devices have been tried for separating the solid from the liquid, of which the most obvious is the double receptacle (Fig. 14).

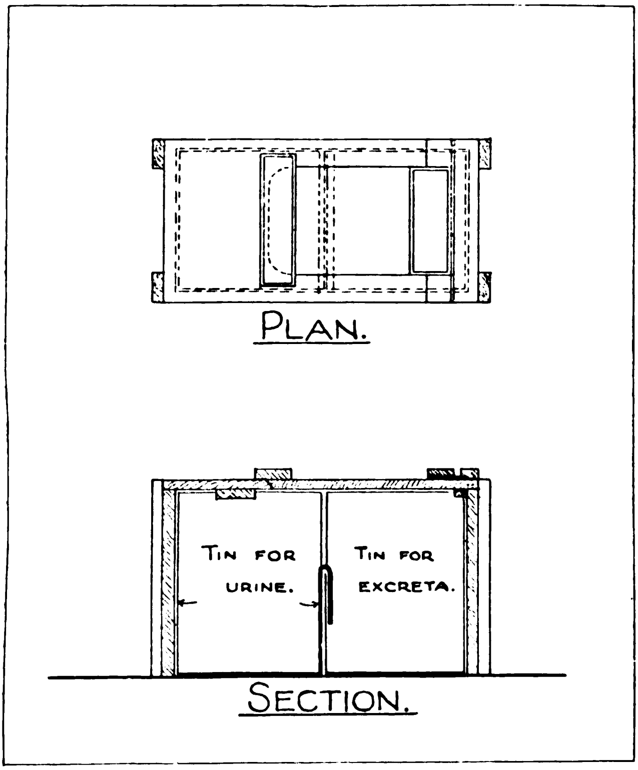


Fig. 14.

With such an arrangement there was a liability for the receptacle to become misplaced and the junction fouled. An ingenious modification was by placing a small cresol drum inside a slightly larger one, the smaller drum being bent in such a way as to form a channel, down which the urine could pass into the larger receptacle (Fig. 15).

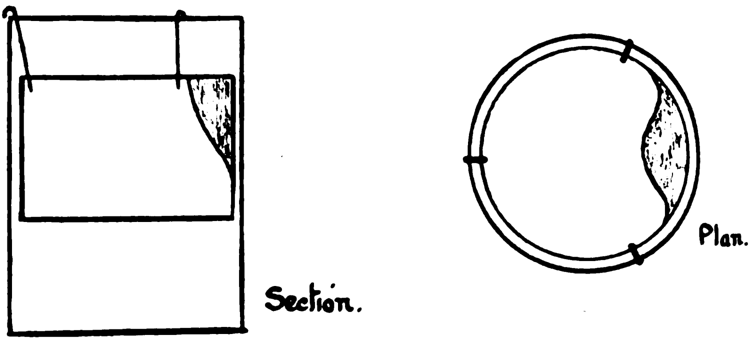


Fig. 15.—Improvised latrine bucket and urine separator. Receptacle improvised from metal oil drum; urine separator from smaller drum, bent to form urine-chute, suspended low to avoid scrotum.

Another modification is also shown in Fig. 16.

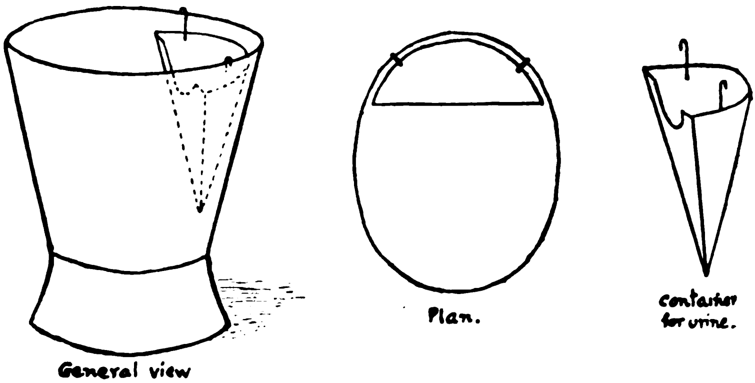


Fig. 16.—Urine Separator. A cone-shaped tin suspended at front of latrine bucket; edge shaped as shown to avoid scrotum.

Various designs were invented to allow of the urine being conducted directly to a soakage pit along a trough attached to the inner side of the front wall of the latrine seat. Many of these designs defeated their own object owing to the trough being placed too near the seat.

Lieut.-Colonel Sharp devised an arrangement which acted automatically and required no attention. A seat in the form of a stout pole, supported on forked uprights, was erected, with a fall of 2 in. in 10 ft. towards one end. A small trough was made out of biscuit or other tins and nailed to the posterior

surface of the pole. The free edge of the trough, which was rounded, projected about 4 in. behind, and about 4 in. lower than the upper surface of the pole. The trough emptied into a pit or receptacle at the lower end, towards which there was a fall of 2 in. in 10 ft. The fæces fell into the bucket, while the urine was caught in the trough and flowed along to the pit or receptacle at the end. The pole seat was rubbed over with paraffin and the trough flushed down with cresol solution daily.

A very useful type of latrine utilizing this device was designed for the rest camps on the lines of communication between Taranto and the Channel ports, known as the Mediterranean line of communication (Fig. 17).

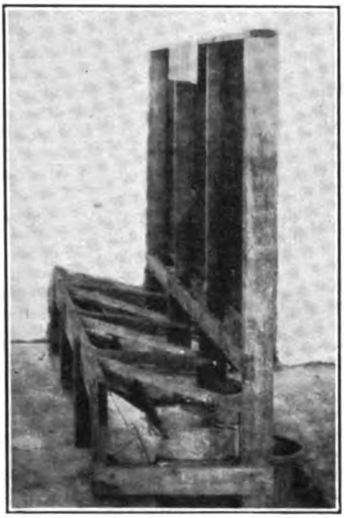


Fig. 17.—Latrine with urine trough (Mediterranean Line of Communication).

The trough was broad and well placed, the seat sloping so as to place the user in a semi-squatting position, and the structure was designed to ensure the greatest economy in wood, of which, at the time, there was a great scarcity. The great advantage of this pattern was the very perfect separation of solids and liquids, resulting from the relative positions of user and receptacles. No attempt was made to render it fly-proof, and cresol solution had to be freely used, or, as was actually

done, the bucket contents were cleared to the incinerator by a permanent attendant at the earliest possible opportunity.

Many improvised receptacles were used, such as cresol

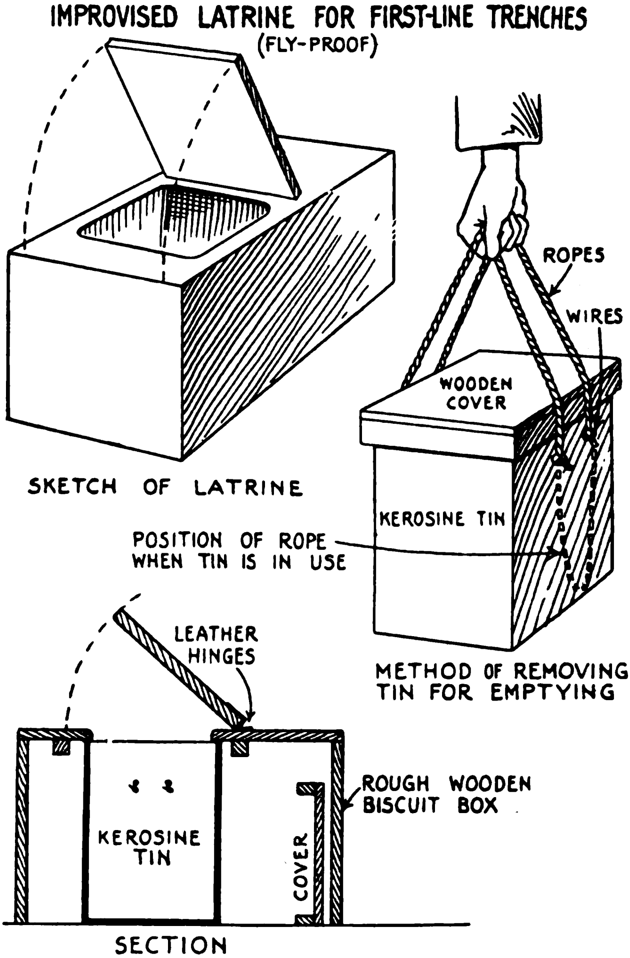


Fig. 18*a*.

drums, biscuit tins, and petrol tins; seats were constructed from biscuit boxes, and many ingenious forms of single latrine were made in this way (Figs. 18*a* and 18*b*).

Several varieties of single latrine were invented, in some the receptacle was removed through a trap door in the front or behind, in others the top could be raised, and in others the complete casing had to be lifted.

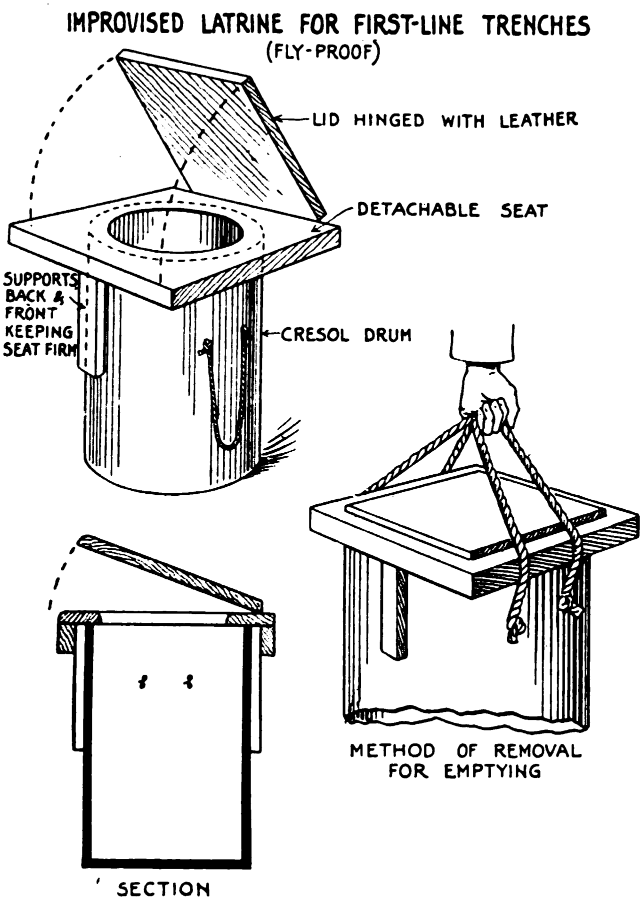


Fig. 185.

An excellent type was that in which the receptacle fitted closely, like a drawer, and was removed by sliding through a trap in the front. In a type of latrine suitable for listening posts, advanced saps, crater lips, and positions close to the enemy, the lid was constructed so that in falling it held a considerable quantity of air, which when compressed acted as a cushion. A hollow block of flexible rubber on each side added to its efficiency. It was practically silent when set over a deep pit.

Biscuit tins were inferior to the 4-gallon petrol tins. As a general rule they were unsuitable for use as latrine receptacles

except where immediate individual incineration was employed, as in Fig. 12.

Special provision had to be made for non-European troops and coloured labour companies. Certain difficulties arose from traditions and religious customs. With Hindus, for instance, any automatic fly-proof receptacle which involved contact with the person was not permissible. With many other non-European races, on the other hand, there was no such objection, and the device was freely used.

Practically all Eastern peoples adopt a squatting posture, and receptacles had, therefore, to be placed at ground level; any attempt to use sunken receptacles proved a failure, and led to fouling of the ground.

A double receptacle placed at ground level with foot rests, which could be improvised from sandbags, was the best form. Whenever possible, however, some form of fly-proof, self-closing cover was adopted. It was always well to make provision for speedy removal and incineration.

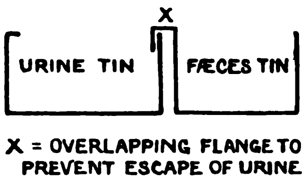


Fig. 19.—Durbar pattern latrine (Indian).

Fig. 19 is an illustration of an excellent type of improvised latrine which was extensively employed in the Eastern theatres of war. Two tins were used, the posterior one having an anterior flange, which overlapped the posterior wall of the first receptacle, so as to bridge the gap between the two and prevent fouling. A fly-proof cover may be made of a "tambourine" of loose sacking sewn to an iron hoop at its circumference. Another type of latrine used consisted of an oblong funnel fitting into a small model soak pit; the funnel was plugged with grass or straw, and acted as an efficient strainer; the solids were thus retained and the liquids passed into the ground.

An ingenious device was adopted during the war for fly-proofing Hindu latrines without arousing religious objections. The double receptacle was covered with sacking, supported by two metal hoops, placed at each end. A loop was fixed to the sacking, by which it could be lifted and suspended

from the screen placed immediately behind each receptacle. This was used with success in Mesopotamia (Fig. 20).

There was some objection to this device on the ground that, if badly managed, the sacking cover became fouled; to obviate this the cover was soaked in cresol solution. This should only be regarded as an emergency measure to meet a temporary shortage of latrine personnel.

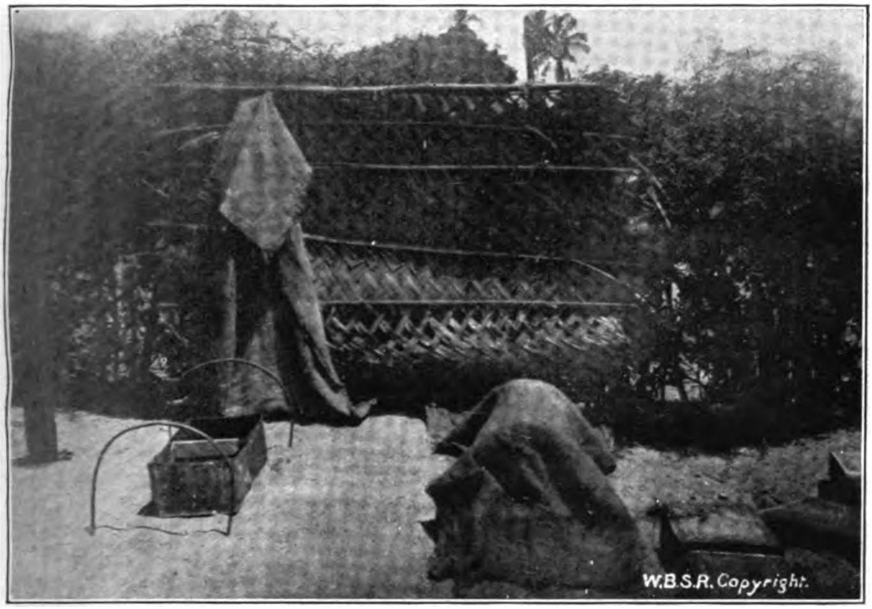


Fig. 20.

Indians, and other Eastern races, do not use latrine paper, but cleanse themselves with water. It was necessary, therefore, to provide arrangements by which the process could be carried out without pollution of the ground round the latrine. A washing place, or *âbdast*, had always to be provided as close to the latrine as possible. It consisted of impervious channels, lined with tin or cement, falling towards a covered soak pit (Fig. 21).

An excellent portable latrine for gangs of labourers or for Indian troops in the trenches is shown in Fig. 22.

There are foot rests on the top and a sliding cover. The cover may be removed from the receptacle so as to enable the

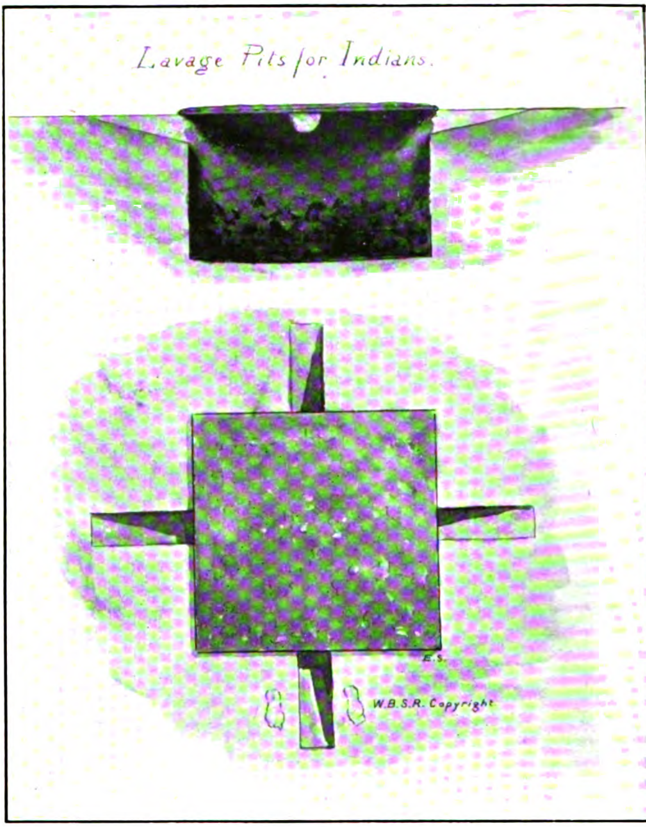


Fig. 21.

contents to be dealt with by burial or incineration. The sliding cover is liable to jam if made of wood; a tin lid proved more suitable.

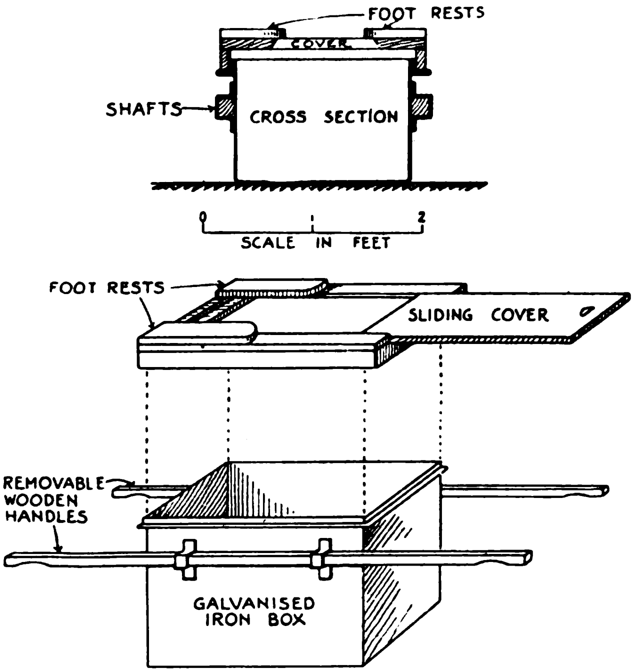
Deep Pit Latrines with Fly-proof Covers.

The deep pit latrine was practically a permeable cesspit. It was consequently liable to foul water supplies, and might act as a prolific fly-breeding centre; but, under the conditions of warfare, it had many advantages. Pollution of the soil was, in any case, unavoidable where actual fighting was going on, and careful management could do much to reduce fly breeding. The open deep pit latrine such as that described

in former field service manuals was never, however, admissible (Fig. 23).

It was, unfortunately, often used in the early days of the war. It provided the maximum opportunity for fly breeding and fly infection, and was liable to become objectionable.

As the war progressed, the deep pit method was greatly developed on sanitary lines. On the Western front the fly-proof



PORTABLE FLY-PROOF LATRINE
(NATIVE PATTERN)

Fig. 22.

deep pit latrine was much used, and also, for a considerable period, in other theatres of war. In Egypt, owing to the large amount of fly breeding which took place, it was eventually replaced by incineration.

A high subsoil water precluded the use of this type of latrine, but, apart from this consideration, it was an invaluable method of disposal of latrine contents in front line areas, where incineration was impossible. At Port Said, Imbros, Sidi Bishr and in the Canal Zone, deep trenches were used with success even where there was high subsoil brackish water.

The fly-proof deep pit latrine was practically "fool-proof," there was no handling of dirty receptacles, the seats had automatic self-closing covers, very little care was required except to keep the seats clean and to see that the pit did not become overfilled. When the pit was full to within 3 ft. of the top, the cover was transferred to a similar pit previously prepared and the old pit slowly filled in after sprinkling the contents with 10 per cent. cresol solution. The site was then covered by oiled sacking let in below the turf and extending outwards for 3 ft. in every direction or, if this could not be done, the surface was covered with clay rammed down as tightly as possible.

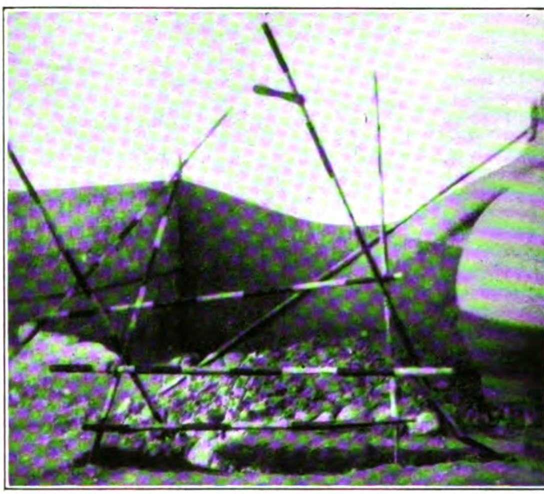


Fig. 23.—Open deep pit latrine.

These pits were dug as deeply as possible. The dimensions of a pit for 100 men would be about $2\frac{1}{2}$ ft. wide and 6 ft. long. Many were as much as 12 ft. deep and appeared to have a practically unlimited capacity owing to the liquefaction which took place.

A useful device to prevent fouling of the woodwork was to have the back and front sloping outwards. No longitudinal beams were permissible, as they were liable to become fouled.

Figs. 24 and 25 show a type of deep pit latrine frequently used in France. If necessary, the sides of the pit were shored up by wooden supports. The cover is fixed on to beams let

into the ground along the front and back of the pit. Seats were constructed from biscuit boxes with the tops and bottoms removed. Smooth strips of wood were used to form the surface of contact, and a self-closing cover was provided,

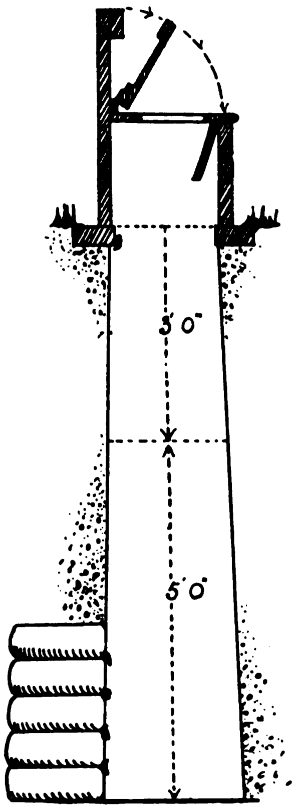


Fig. 24.

which was prevented from rising beyond the vertical by a suitable back rail. Paper receptacles should be attached to the latrine. A metal guard was placed along the inside of the woodwork in front, to direct the urine into the pit. In Mesopotamia a sandbag revetment was frequently used to hold up the sides of the pit, whilst corrugated iron and reed hurdles were also tried.

Deep pit latrines of this type were used with the greatest success as public conveniences over the area of the Somme offensive in 1916. A shell-hole was always liable to be used as

a latrine, and it was found that at every halting place the shell-holes were foul and swarming with flies. The halting places for infantry advancing to the attack were generally in the neighhood of the artillery supporting the attack ; so that there was

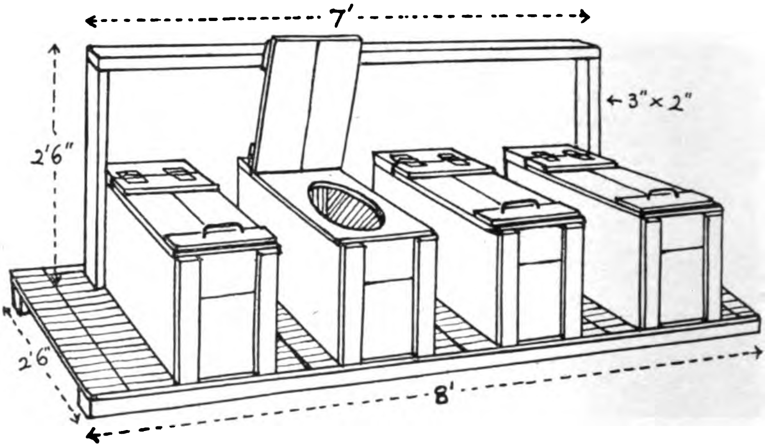


Fig. 25.—Fly-proof latrine made of biscuit boxes.

grave danger of fly-borne infection spreading from " carriers " amongst the infantry to the artillery in the neighbourhood. This danger was overcome to a very large extent by constructing deep pit fly-proof latrines along the line of march and carrying the seats and covers of these latrines forward with the advance of the troops. Any system of receptacle latrines and incinerator was of course impossible during these operations.

In the construction of deep pit latrines it was essential to avoid cracks through which the flies could pass, one of the great difficulties with regard to this form especially. In the Eastern theatres of war a constant watch had to be kept on the woodwork in order to have any defect promptly repaired.

The larvæ of any flies which may breed in these pits work their way to the surface of the ground and there pupate. These could be trapped by a layer of oiled sacking placed a few inches below the surface of the ground and extending outwards from the pit for 3 ft.

In the trenches deep pit latrines (Fig. 26) were placed in T or L-shaped saps (Fig. 27). The pit was dug as deep as possible, generally about 4 or 5 ft., and covered by a single seat with self-closing cover.

When filled to within about 1 ft. of the surface a fresh pit was dug on the side next the trenches, the old pit filled in and the sap made good over the top in order to cut off the foul ground from the trench area.

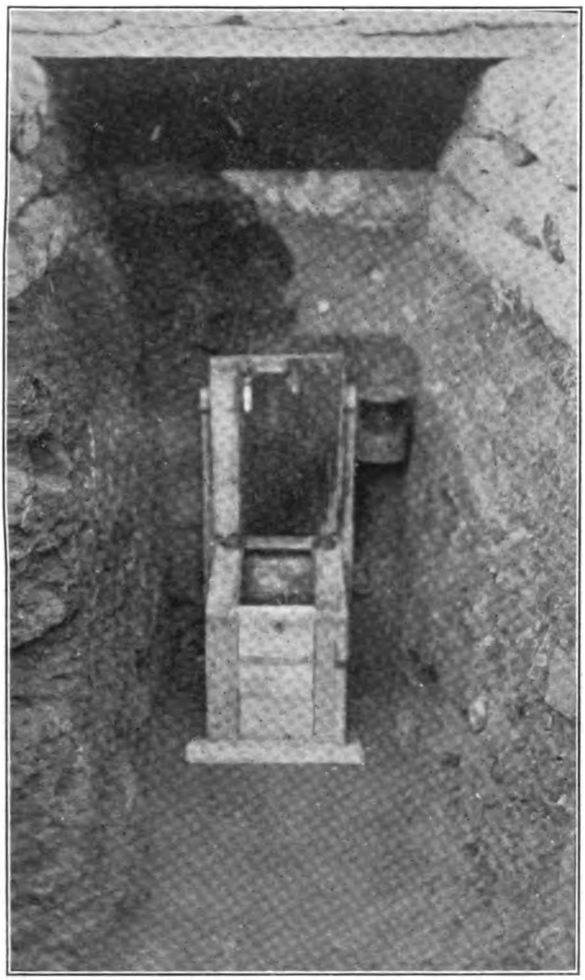


Fig. 26.

These pits proved of value in certain sectors and were especially suitable for communication trench latrines.

The digging of pit latrines in front line trenches was apt to be interpreted by the enemy as an offensive measure, such as the construction of machine gun emplacements, and trench mortars were consequently brought to bear on the men constructing

Fig. 27.—Model section of trenches, showing latrine saps.

the latrine. Frequently men were sniped whilst in the latrines, generally when entering or leaving. The latrine saps had consequently to be constructed of a sufficient depth to preclude such a risk.

Various modifications of deep pit latrines were designed. Deep pit latrines were constructed covered by a strong wooden platform with trap-door openings and self-closing lids, which rested against the back of the user. This was considered

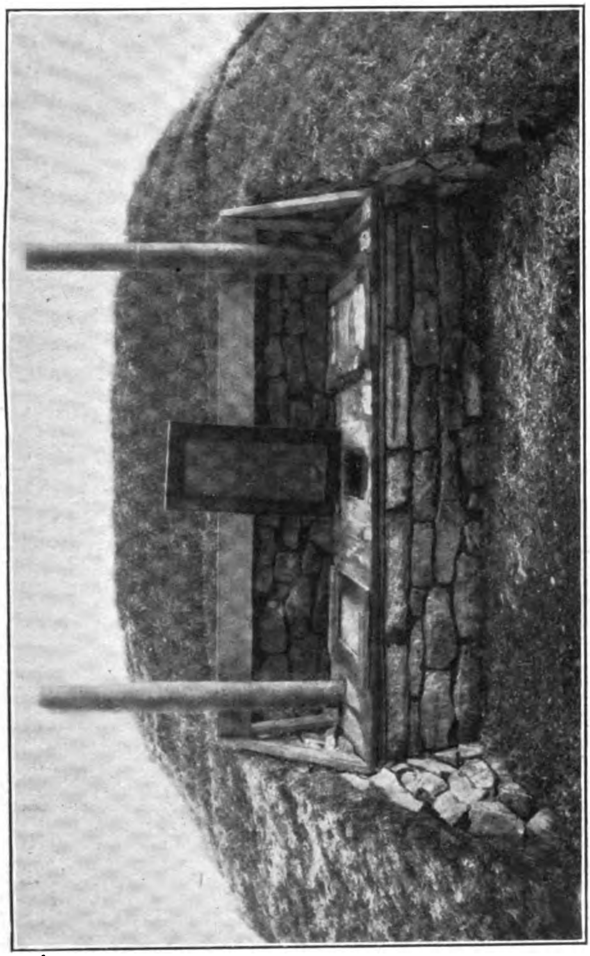


Fig. 28.—Pit latrine (Salonika).

objectionable and traps opening sideways were designed so that the lid could be supported by the boot.

These trap-door pits were not popular with European troops but were used with success in at least one area of the French

front. The chief advantage was that they could be very rapidly constructed and did not need a great quantity of wood.

For hilly country deep pit latrines were designed so as to use the natural slope of the ground to economize material. The wooden seat was supported by stones or boulders rendered fly-proof by filling in the spaces between the stones or boulders with mud or clay. (Fig. 28.)

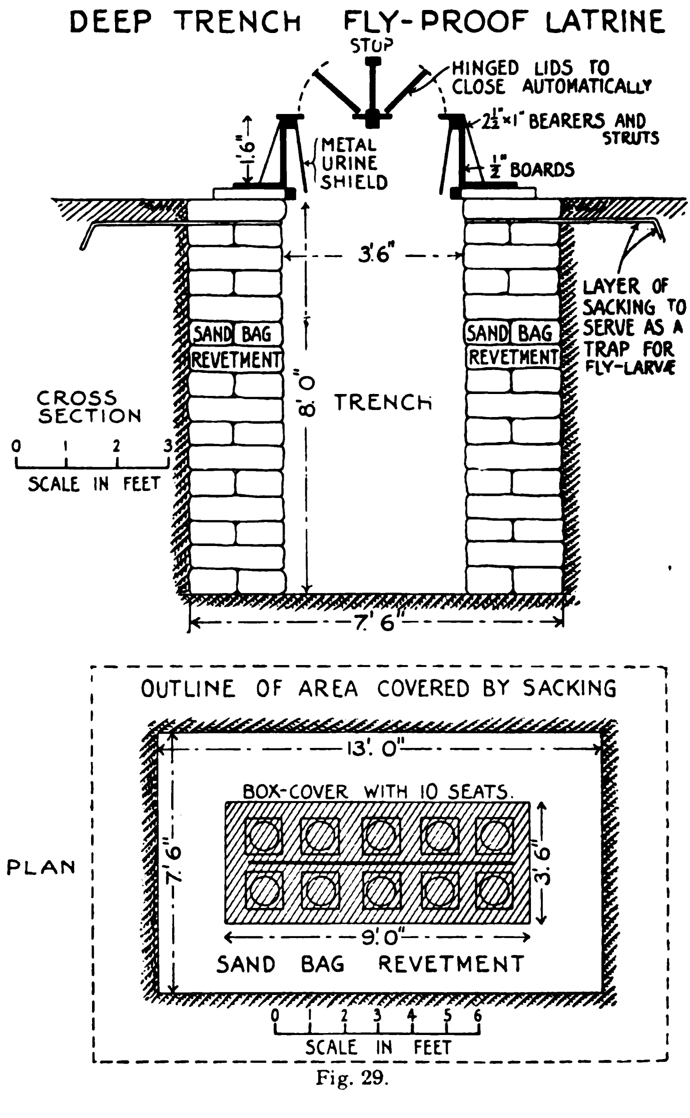


Fig. 29.

Fig. 29 illustrates practically all the essential points in the construction of the fly-proof deep pit latrine. The features of special note are the sandbag revetment, the metal urine shield and the sacking larva trap. Such a pit would hold a great amount of material and last for a very considerable period.

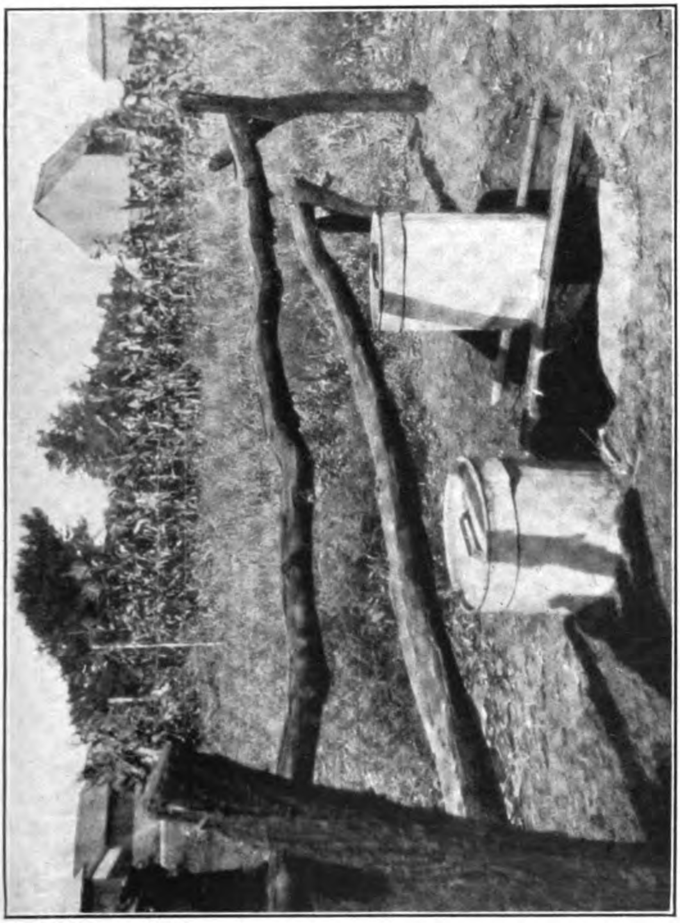


Fig. 30.—Latrine showing method of fixing pedestal shafts.

A good modification of this type of latrine was used in East Africa. Pedestal shafts, made of cresol drums, with fly-proof, self-closing covers and supported on iron rails were set over the deep pit. The pit was roofed in by timber and matting or corrugated iron, which was covered by beaten-down earth.

The cresol drum was flanged, as shown in Fig. 30, so as to fit firmly on to its supports.

In all deep pit latrines there is a danger of fly invasion; to avoid this, fly-papers might be suspended inside the pits to reduce the danger, or the smoke-box system, which was used in East Africa, might be adopted. This consisted of lowering into the pit twice daily a brazier, perforated kerosene tin or some similar receptacle full of smouldering leaves, wood or other suitable material which gave off a good volume of pungent smoke. The smouldering mass was lowered into the pit by means of a chain attached to a cap or cover, which sealed the entrance and prevented fumes and flies from escaping. This process must be thoroughly carried out, otherwise it is useless. Another type of smoke latrine was also used, having a fire-box at one end and a chimney at the other, so that the smoke was continuously passing through the pit.

The management of deep pit latrines was a point upon which there was some divergence of opinion, some authorities advocating the regular use of chloride of lime and other antiseptics, whilst others condemned the use of any antiseptic until the time for filling in, when 10 per cent. cresol solution was sprinkled over the surface of the contents.

There is much to be said in favour of the second method; in such pits an action closely comparable to that which is seen in a septic tank takes place, with liquefaction of the contents. Any antiseptic added interferes with this action and tends to shorten the life of the pit. On the other hand, it was urged that by using antiseptics the objectionable smell is much reduced. The same result may, however, be obtained by suitable ventilation of the pit through shafts carried up several feet above ground level (Fig. 28).

Receptacle Latrines and Burial.

This system corresponds closely to the last but suffers from the great disadvantage that foul receptacles have to be handled. There were, however, situations where it was the only method available. In certain trenches, owing to high water level, proximity to the enemy and for other reasons, it was impossible to install deep pit latrines. Under such conditions, in the early days of the war receptacles were used and the contents were buried in any convenient shell-hole under cover of night. The degree of burial depended upon the sanitary man whose duty it was to carry out the work; it was not subject to inspection, and it was an uncongenial and dangerous task.

With such a system the danger of fly-borne infection was greatly increased. To meet this problem a system was devised by which all the contents of latrine buckets were emptied into special pits dug at some suitable spot behind the line, but accessible.

Generally the site chosen was near some abandoned side trench, leading off the communication trench, where pits could be dug in comparative safety and disposal carried out under shelter. These pits were generally about 4 ft. square and 4 or 5 ft. deep; two were constructed, one for solid and the other for liquid refuse. They were under the control of the battalion medical officer, who chose the site and saw that the pit was properly filled in before handing over to another unit.

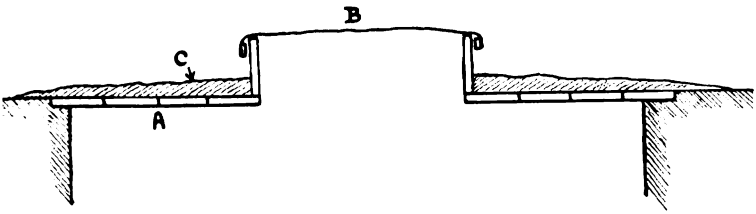


Fig. 31.—Fly-proof cover for rubbish pit. A—Planks. B—Canvas cover on wood frame. C—Earth heaped on planks.

Such a system was easy to control but required a certain amount of organization. Covers were provided for the receptacles during transit to prevent fouling of the trenches through splashing. It was essential to see that the pits were not placed too close to any occupied trench or dugout; 60 ft. was the distance fixed in some of the sectors on the Western front. It was not always easy to get such a system carried out and up to the end of the war in certain areas the more primitive and insanitary method of disposal was found to persist.

The system of receptacle latrines and burial was also occasionally necessary behind the line, in which case the disposal pits were made as deep as possible and covered by a fly-proof cover either of wood or oiled canvas with a covered trap through which the refuse and excrement were introduced (Fig. 31).

These pits were also useful as an emergency measure, should the process of incineration break down or where for any reason it was impossible to construct a proper incinerator.

The site for each pit had to be carefully chosen, more especially with regard to the danger of polluting any water supply.

The "Shallow Trench" or "Straddle" Latrine.

Before the war and during the early days all teaching on the question of latrines revolved round two types, one of which was advocated, the other condemned. The open deep pit, as already noted, was rightly condemned as an insanitary and dangerous type; on the other hand, there was a tendency to praise unduly the shallow trench latrine for its theoretical adherence to sanitary principles.

The shallow trench latrine, though undoubtedly useful in certain circumstances, may be said on the whole to have proved a failure. But for a war of constant movement it was practically the only available form of latrine and, if managed by trained soldiers, was more or less successful, though in the hands of careless or rapidly trained troops it was liable to become a teeming fly-nursery. As a matter of experience it was the exception to find a shallow trench latrine which approximated to sanitary standards: it was extremely difficult to persuade the soldiers to fill in the earth after using the latrine and in wet weather the whole area tended to become a trampled mire of filth.

As such a type of latrine is essential for troops on the march, the greatest care was necessary to train all soldiers in its proper construction and management. The trenches have to be dug according to the recognized rules, they have to be well situated and carefully looked after, and above all things, must be regarded only as a temporary expedient to meet a special need.

In some districts, owing to the high level of subsoil water and for other reasons, it was necessary to adopt the shallow trench system more permanently, and in this case oiled boards were used to form fly-proof covers, their efficacy depending largely upon the care of those using the latrine in replacing the boards.

Experience of this type of latrine was not, however, satisfactory; several attempts were made to use it on the Western front, where the ground water prevented the installation of deep pit latrines, but without any great success. In the East, however, it is said to have been used with moderately good results. (Fig. 32.)

The Lumsden wet privy is worthy of mention, though it was not extensively used by the British troops during the war. A fly-proof seat is set over a large barrel receptacle in which is placed an anti-splash board, which can be lowered into the liquid in the tank. An overflow pipe is provided

leading into a second barrel, a soak pit or subsoil trenches. This privy works on the principle of the ordinary septic tank (Fig. 33). Experience of this device as used at Mudros was unfavourable owing to smell, but this may have been due to faulty management, as at first it acted in a satisfactory manner.

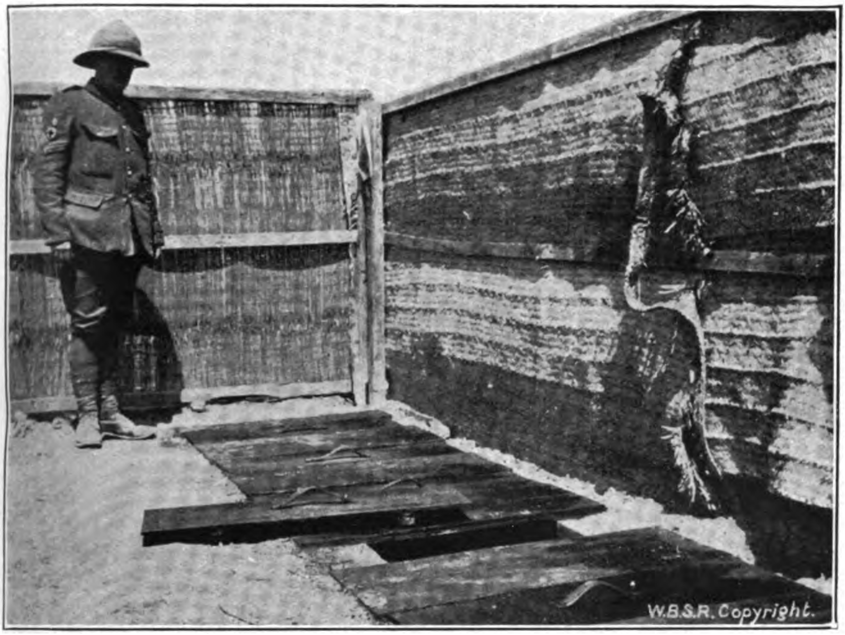


Fig. 32.

Attempts were made to adapt the "dry earth system" to military requirements. Several experiments were carried out in home camps, but it was never used on a large scale in the army. With careful supervision and a small picked unit, this method of disposal can be carried out with perfect success. It is essential that there should be complete separation of the urine from the fæcal material, also that latrines and storage rooms should be fly-proofed.

Separation can be effectively carried out by having a posterior receptacle for the solid excrement and a cement wall and drain in front to catch the urine.

The excrement is well mixed with finely sifted earth and stored in a fly-proof chamber; it is forked over and turned

daily for the first few days. If the process works in a satisfactory manner, the whole mass is turned into a fine inoffensive mould in a few weeks' time. Such a system carried out on a large scale is very liable to break down and any neglect or carelessness may lead to disastrous results.

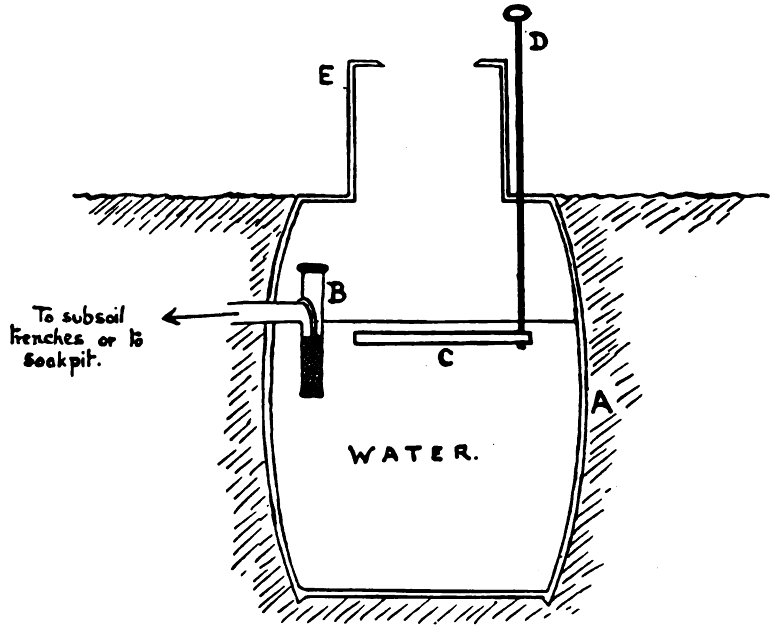


Fig. 33.—" Lumsden " wet privy. A—Barrel. B—Overflow. C—Anti-splash which is raised or lowered by handle D. E—Seat fitted with fly-proof cover (which may be made to raise and lower C automatically).

Disposal of Urine.

With a proper drainage system the disposal of urine presented no special problem. But under active service conditions a drainage system was rarely available and special arrangements had to be made for dealing with approximately 300 gallons of urine daily from a battalion.

The evaporation of urine could only take place in exceptional circumstances, and land or water disposal had to be adopted. In the field, any fouling of streams was especially undesirable and the facilities for purification offered by the soil had to be fully utilized.

Infective urine from hospitals could be sterilized or evaporated in a special tray, such as that employed in the McMunn incinerator (Fig. 34).

This incinerator required much attention but was valuable since it provided a safe method of dealing with infective excreta. A good deal of fuel was required, but the following figures fully justified its use in special circumstances. In twenty-four

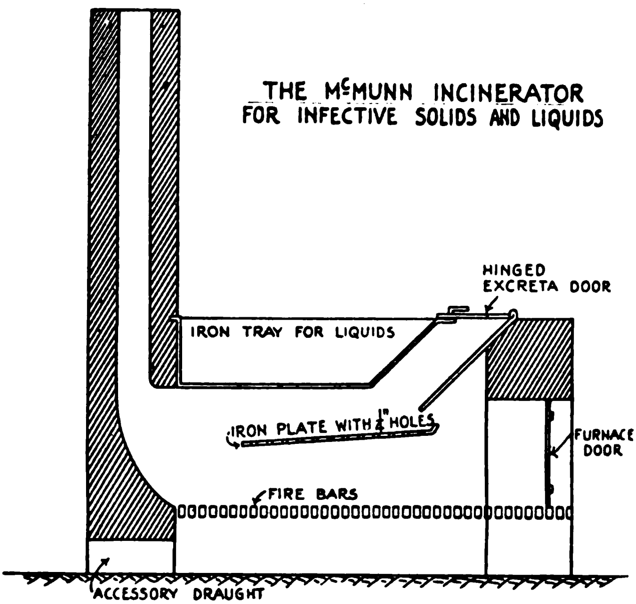


Fig. 34.

hours' work, 130 gallons of liquid and the excreta of 200 patients were disposed of, with a fuel expenditure of 180 lb. of wood and 50 lb. of saw-dust with hospital refuse added.

The experience of the war proved conclusively the value of what may be termed the " model closed urine pit " (Fig. 35), such as was used in Indian cantonments before the war.

A cubical hole is dug in the ground ; it is then filled in with stones, brickbats or perforated tins graded so that the smaller sizes are at the top of the pit.* Pipes, which may be improvised from waste tins are inserted deeply into the pit and communicate with funnels or troughs which form the urinal.

* In the Indian cantonments these pits were constructed with the small stones below and the larger stones on the top; and this was the best form of construction as the liquid evaporated more rapidly or was better distributed into the soil.—W. G. M.

Frequently these pits were constructed with pipes passing only a little distance below the surface. With a fairly loose soil, perforated cresol drums placed over the pit were recommended; and urinals of this type were used in various districts, more especially in Egypt. The pit should be roped off from corner

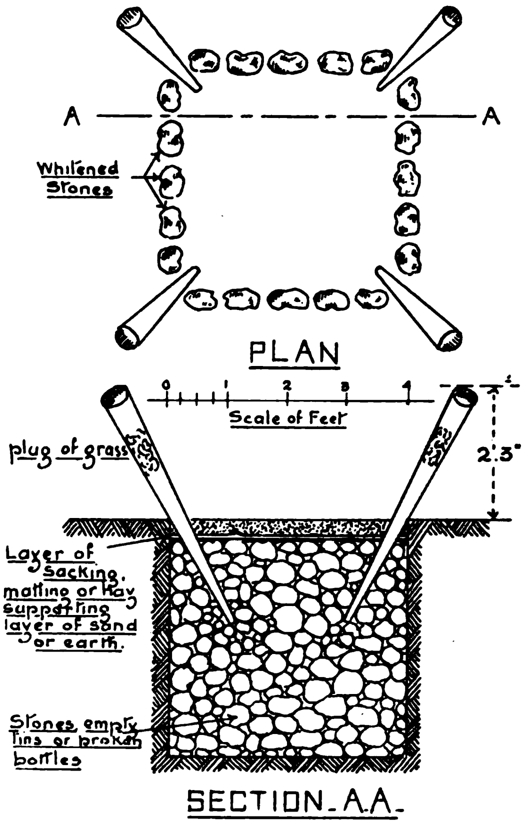


Fig. 35.—Diagram of urinal and soak pit.

to corner so as to prevent soldiers walking over the surface, and the urinal should have a perforated guard to prevent articles which might be thrown into the urinal from blocking the pipes.

These soak pits dispose of the liquid into the surrounding soil, and in some degree encourage the destruction of foul material by bacterial action. The urine passes into the depths of the pit and cannot give rise to nuisance or danger unless there is some source of water supply in close proximity. The value of the soak pit depends very largely upon the permeability

of the surrounding soil; in sand, for instance, the pit may last almost indefinitely and give rise to no nuisance; in clay, on the other hand, it may quickly fill and decomposition give rise to offensive odours. But even in a very impermeable soil these pits were used with success, as was frequently the case on the Western front, when worked upon a twin system by using two pits alternately and never allowing either to be overworked. In size the pits varied from a 4-ft. to a 10-ft. cube.

Old and useless tins which had been passed through the incinerator were ultimately got rid of by using them for filling urine pits, although tins are not so good as brickbats for the purpose. It is essential that they should be well perforated before being placed in the pit. In Macedonia one field ambulance found that a good soakage pit could be made in rock by blasting.

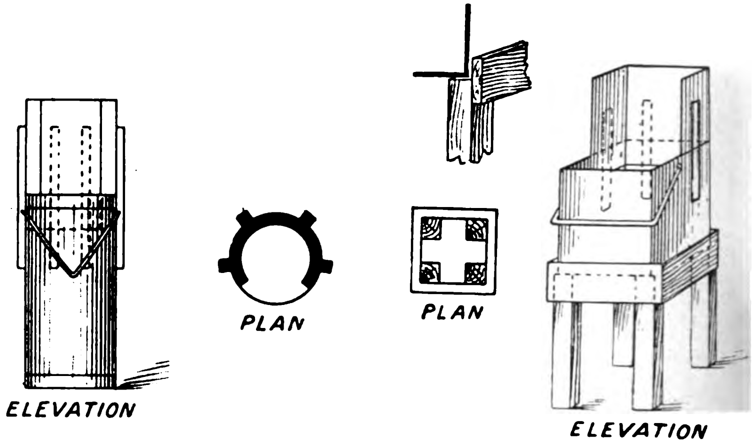
Receptacles were generally necessary for night urine, but it was difficult to see in what other circumstances their use had any advantage over the model pit, for the latter could with perfect safety be placed near tent lines and billets provided there was no liability to contaminate adjacent water supply. Provision of some kind or other had always to be made for night urinals in close proximity to billets and tents, for without such precaution fouling of the ground in the immediate vicinity was inevitable. When receptacles were used they were raised to a suitable height, placed on an impermeable base and rendered visible by whitewash or some other means. The importance of these precautions and of providing night urinals was, however, often overlooked by those in charge of troops occupying billets for a short time only.

Various types of night urinal were devised; a cresol drum with a large metal funnel placed in it, and a cresol drum with the top removed and a curved "guard" attached to the back are characteristic examples.

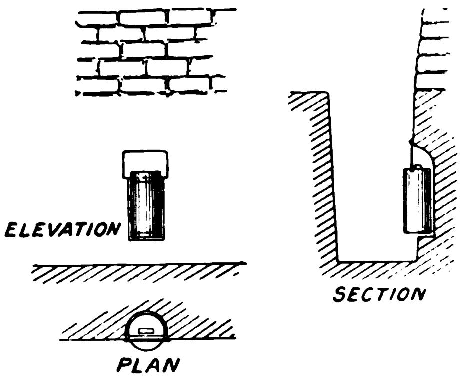
With a high level of subsoil water, the disposal of urine was often very difficult. The problem was solved in some cases by using long superficial drains, filled in with brickbats or stones, but occasionally receptacles had to be used and the contents disposed of at a distance. These conditions were of inevitable occurrence in many of the trenches during the war.

Perhaps the most original type of urinal used in the war was constructed by letting funnels into a large ant-heap (Fig. 37), and, though such a device must be regarded as a curiosity, it emphasizes the value of ingenuity in solving sanitary problems. This urinal was used with great success at Dar-es-Salaam.

Evaporation was tried by using layers of trays containing saw-dust through which the urine percolated. Occasionally such a system was worked with success by small units but it was not one which lent itself to general use.



Night urinals.



Trench urinals.

Fig. 36.—Night and trench urinals.

Disposal of Dry Refuse.

Ordinary dry camp refuse consisted mainly of cinders and other combustible material, and was therefore useful for mixing with excrement destined for the incinerator. A battalion yielded between 600 and 1,200 lb. of dry combustible refuse daily, the maximum being reached in the coldest winter months. Refuse could either be burned or buried. The latter method is

unsatisfactory and should be adopted only as an emergency measure.

Where provision was made for incinerating fæcal matter, all camp refuse except bottles, tins and paper passed to the incinerators, but where incineration was not adopted the dry

Fig. 37.

refuse was destroyed in some form of open incinerator. An open incinerator consisted of a grid upon which refuse was burned, a containing wall to hold the refuse and prevent it from blowing about, and draught holes below the bars to encourage combustion. The ordinary turf incinerator met all these requirements. It had a square shape, walls made of sods, bars placed at 9 to 12 in. from the ground, and four draught holes, one being large enough for raking purposes. The whole was strengthened by stakes driven into the ground at the four corners. Many such incinerators were used on the Western front, and though they eventually burned through and were not very strong, they often served as a valuable temporary measure when bricks were scarce.

Not only were bricks often difficult to obtain but bars were also scarce. To overcome this a form of turf incinerator was used which dispensed with bars, the air being admitted by means of cross trenches dug from the draught holes and filled with tins (Fig. 38).

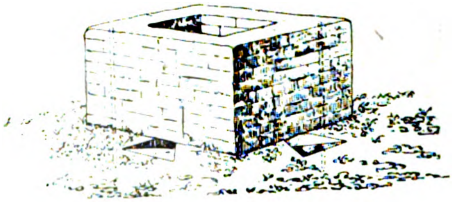


Fig. 38.—Turf incinerator.

Another very suitable incinerator, where material was lacking, was made by cutting a bay in a bank or hillside, leaving ledges for supporting the bars.

A horseshoe-shaped incinerator, made of turf or stone, was frequently used and was easy to construct, but was more or less of the nature of a makeshift. Where bricks were available, the best course was to construct a proper open brick incinerator.

Fig. 39.—Square incinerator improvised from tins (Salonika).

The square type, made of brick, mud or tins, was freely used (Figs. 39 and 40), but objections to this type were, that there was very little protection from rain; that there were angles in which unburnt refuse accumulated, and that fresh refuse did not necessarily fall into the heart of the fire.

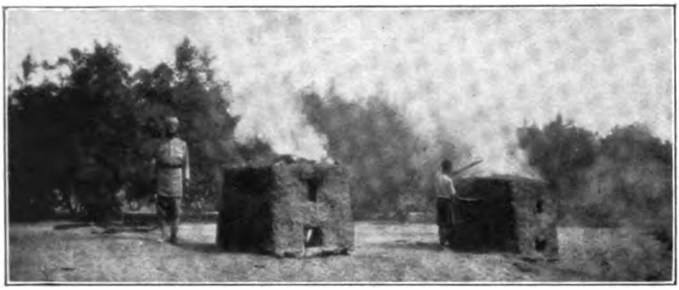


Fig. 40.—Square incinerator made of mud (Egypt).

The "beehive" incinerator was free from these defects. It had no angles, afforded protection against driving rain, and ensured fresh refuse falling into the middle of the fire.

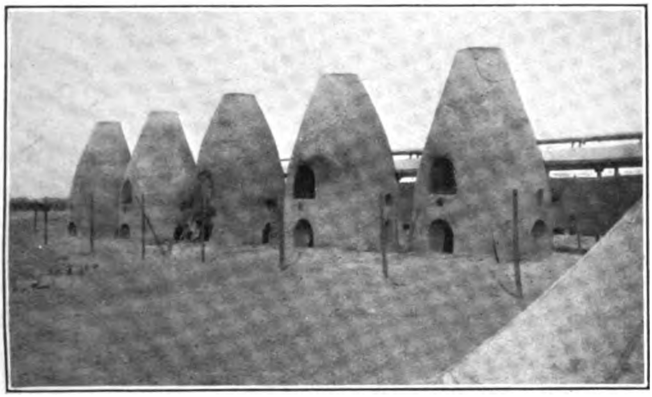


Fig. 41.—Battery of tall, open "beehive" incinerators (Mesopotamia).

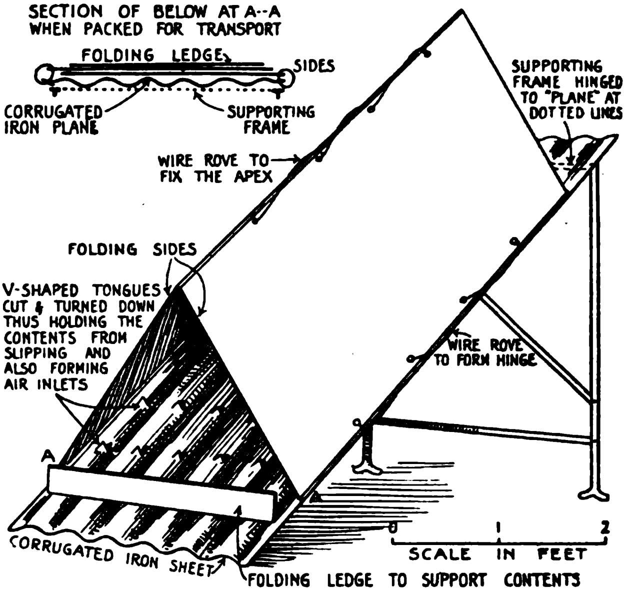
For burning dry refuse, therefore, where it is necessary to prevent paper and other material being blown about, the Sialkote, or "closed beehive" incinerator proved the best.

Various patterns which departed from this type were invented to deal with refuse under special conditions. One of these, the "portable inclined plane" incinerator, was invented by Colonel Lelean (Fig. 42), and is described as follows :—

"This pattern was produced after trial had proved the value of the principle embodied in the improvised inclined plane incinerator, *i.e.*, that

choking of combustion is largely prevented by using a sloping platform on to which ash falls vertically, while flames pass obliquely upwards above the ash level. Holes are left by cutting and turning down V-shaped tongues to form triangles (with 2-in. sides) through which ashes fall and air rises. These holes should be made in rows 6 in. apart at the bottom of each curve of the corrugated iron plane. The tongues keep the incinerator contents from sliding down too rapidly. Tapping the plane shakes ashes out and the contents down.

This apparatus has the advantage that, as it is easily rotated, it can always be turned tail-on to the wind, and the plane can be inclined to any required angle.



PORTABLE INCLINED-PLANE INCINERATOR

Fig. 42.

One or possibly two incinerators, with a plane of 5 by 2 feet, will deal with all the organic non-fæcal refuse of a regiment.

Facilities for transport are obvious, as the whole folds together flat, and there are no detached parts.

The two sides are laced together by wire at the chamber apex, and are also hinged to the base by wire which can be easily replaced."

An earlier pattern, using the same principle and known as the improvised inclined plane incinerator, was found to be quite effective. It is described as follows :—

"This simple but effective incinerator can be made out of 4 kerosene tins, cut and joined as shown, and arched over an inclined plane built of

stones (or tins) plastered over smoothly. The side flanges of the tin cover are embedded in the plaster, of which more is then heaped over the cover, as shown by an end elevation.

Refuse is tipped into the half-cylinder thus formed, and is prevented from sliding down by a series of long nails embedded in the plaster, as shown in transverse section.

If made tail-on to the prevailing wind, this adds to the aspiration draught. If wind blows in an opposite direction, a tin plate as shown by dotted lines across the feeding hole induces an aspirating action which is also effective.

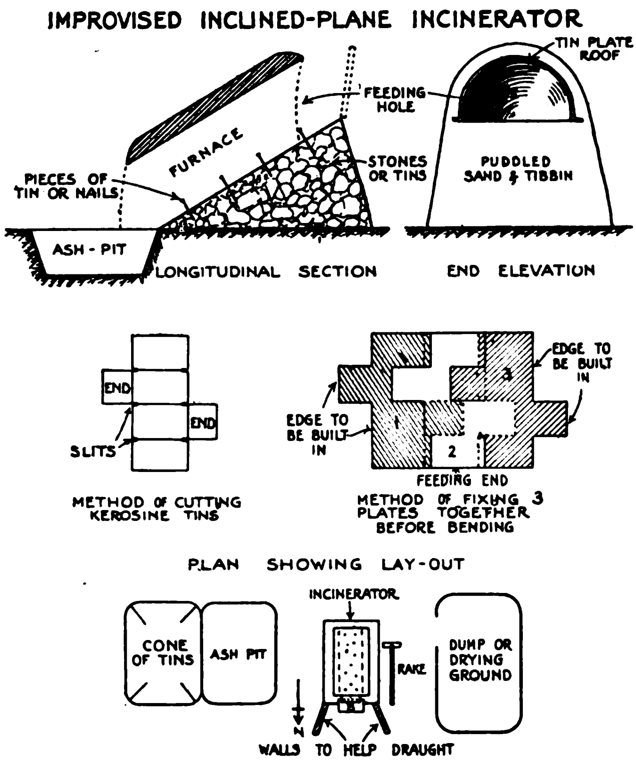


Fig. 43.

Two such incinerators have dealt for some weeks with all organic refuse (except fæces) of a regiment in a dry, hot climate.

Plaster can usually be made by a puddled mixture of one part of chopped straw to 7 parts of clay, earth or sand, with just enough water to render the mass plastic. A hard surface can be obtained by addition of one part of cement to this mixture.

The drying area should be covered by oiled sacking, to protect refuse from wind and flies. The ash-pit should not be more that a foot deep and its contents should not be covered by earth."

A portable field incinerator, made of corrugated iron, and a "basket pattern" incinerator, made of hoop iron or expanded metal, are also examples of the utilization of available material to form sanitary structures (Figs. 44 and 45).

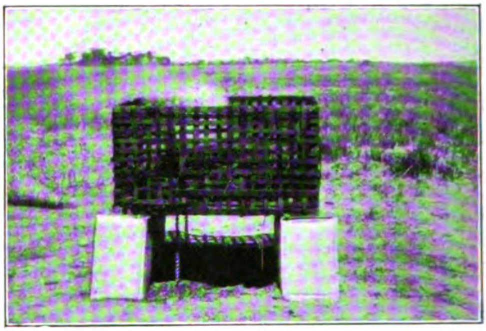


Fig. 44.—Basket incinerator (Egypt).

Various forms of pit incinerator were designed and strongly advocated. Such incinerators solved the difficulty with regard to material, but they were open to various objections. There was always a liability to flooding in rainy weather, and they appear to have been more difficult to supervise. With the Egyptian Expeditionary Force, however, the Welsh pit was used with remarkable success (Fig 46).

The Nissen destructor was much advocated at one time and it was hoped to introduce it into France as a standard pattern. Unfortunately, the reports were not altogether favourable, and many of those responsible for the actual working of the appliance condemned it. Such an incinerator should, however, be a success in careful and skilled hands, and it has the great advantage of economy in bricks and simplicity of construction.

Various modifications of the American cone incinerator were made use of during the war, both for burning manure and also for ordinary dry refuse. The centre cone was made of tins suspended from a main shaft of cresol drums, with tops and bottoms removed and sides perforated; air channels passed under the base of the incinerator to the central shaft. An incinerator of this type proved of value in Mesopotamia, but on the Western front there was always a liability for the channels to become waterlogged (Fig. 47).

Fig. 48 shows one type actually in use. The draught channels, being raised, are, however, liable to become damaged.

The circular trench incinerator was constructed on somewhat similar lines (Fig. 49).

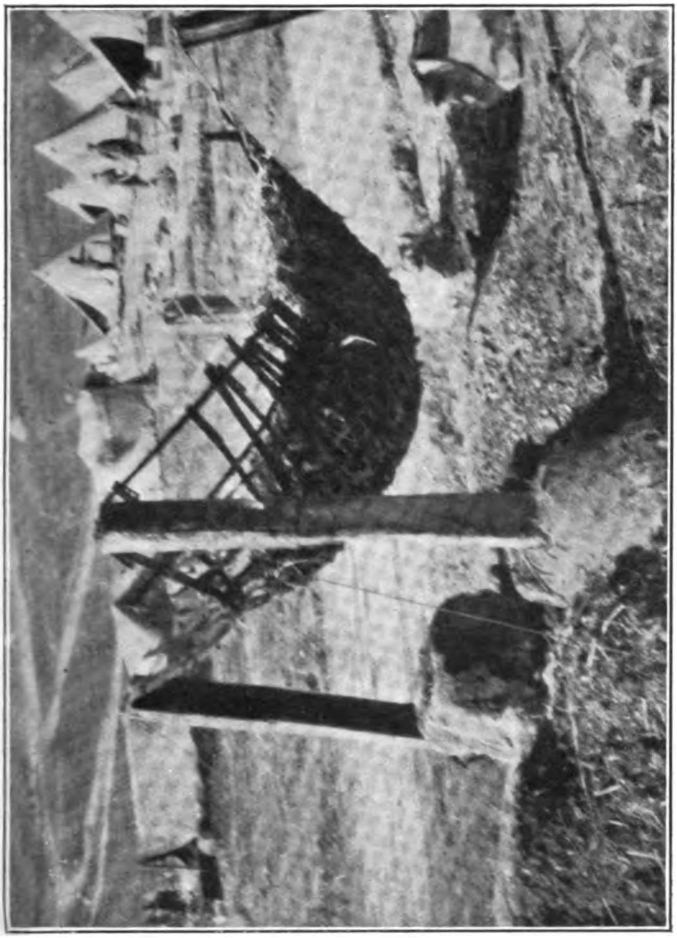


Fig. 45.—Basket incinerator.

An excellent closed portable incinerator for dry refuse could be made from four sheets of corrugated iron (Fig. 50). It is shaped like a sentry-box and fed from the top. The bars are loose and can be shaken so as to allow the ashes to fall through into the ash-pit. The walls are wired together, and the whole can easily be taken to pieces and packed for transport.

A covered refuse receptacle was always necessary for camp refuse so as not to attract flies, to keep the refuse dry, and to prevent its being scattered by the wind. In this connection it was found that refuse accumulating in the cracks of a badly constructed incinerator was a favourite place for fly breeding.

Under certain conditions of front-line work the incineration of refuse was found to be impossible, and it was necessary to adopt a system of burial.

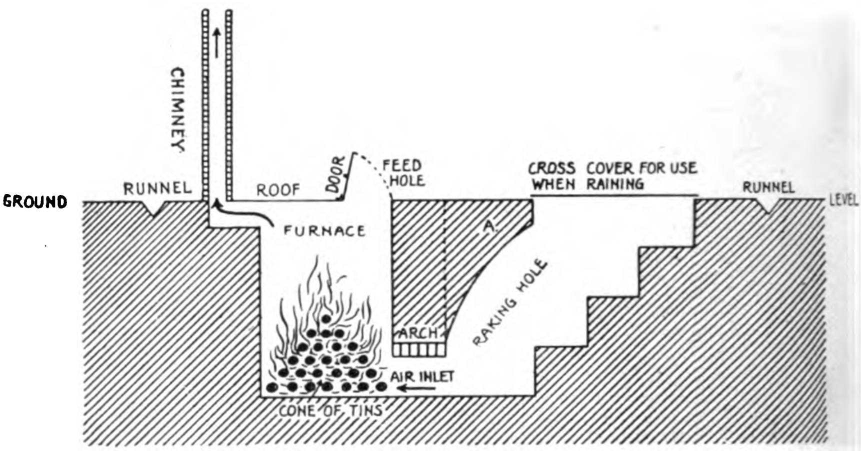
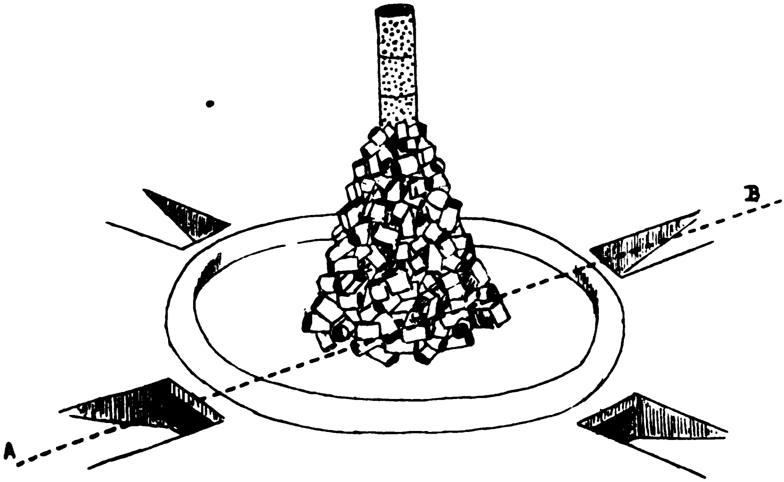
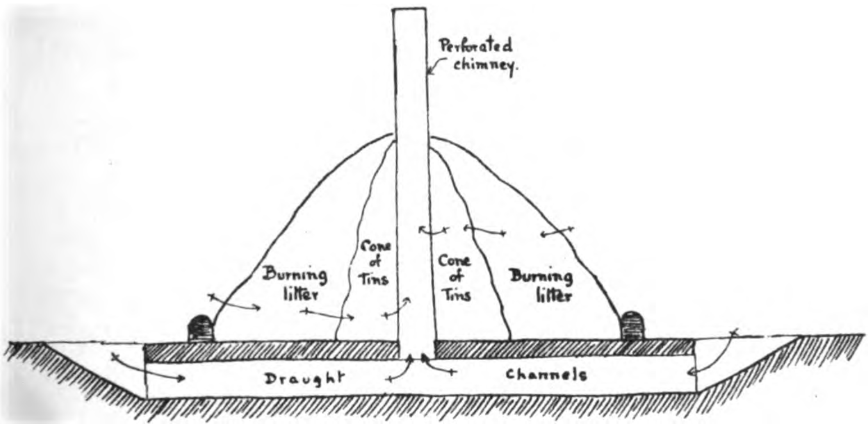


Fig. 46.—Welsh pit incinerator. Vertical section. (Scale ½ in. to 1 in.)

Refuse pits of all sorts were used. The open pit was always unsatisfactory; it attracted and formed a breeding ground for flies and was liable to be misused; in fact, it was quite common to find open pits used as casual latrines. The best type of refuse pit was one which was as deep as possible, and had a properly constructed trap-door for the admission of fresh refuse. If material for covering were not available, one plan was to sprinkle the refuse as it was added to the pit with heavy oil and cover it with a layer of earth.

With regard to the general management of refuse, receptacles were provided in camps and billets and cleared at definite times. Such receptacles could be improvised from cresol drums, tins, sacks, sandbags, and so on, and many variations were invented to meet different requirements. In the trenches, sandbags with self-closing flaps were used; in billets, cresol drums with covers fastened to the receptacles; in cook-houses, galvanized iron bins with self-closing covers. Corrugated iron receptacles were readily improvised.





Section on line. A - B

FIG 47. CONE INCINERATOR.

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At all times economy had to be considered. In the early days of the war incinerators were much misused, and in some cases they served as destructors for the excess rations drawn for

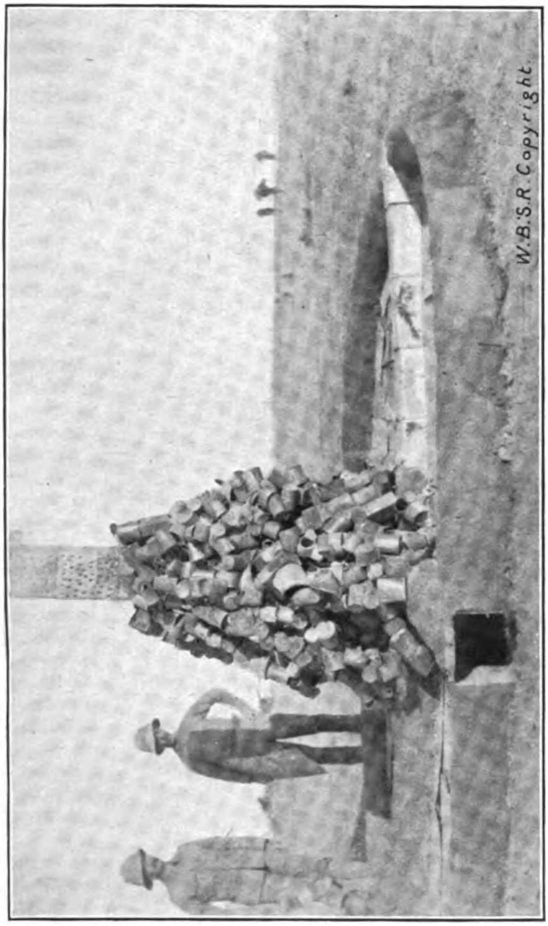

Fig. 48.—Open cone incinerator.

the unit. It was no uncommon sight to see whole loaves, chappaties, large pieces of cheese, meat, and other foodstuffs, dumped by the side of an incinerator or in the process of burning. In addition to food, clothing and live ammunition frequently found their way to the incinerator; on one occasion a sack full of bombs completely demolished one of the best incinerators in Béthune.

In the same way in the earlier days of the war much valuable "waste" material was destroyed; tins were passed through the incinerator and the solder was wasted; fat of all sorts, especially from the grease traps, was cremated; paper was burnt, and many other materials which could have been used were destroyed in this way.

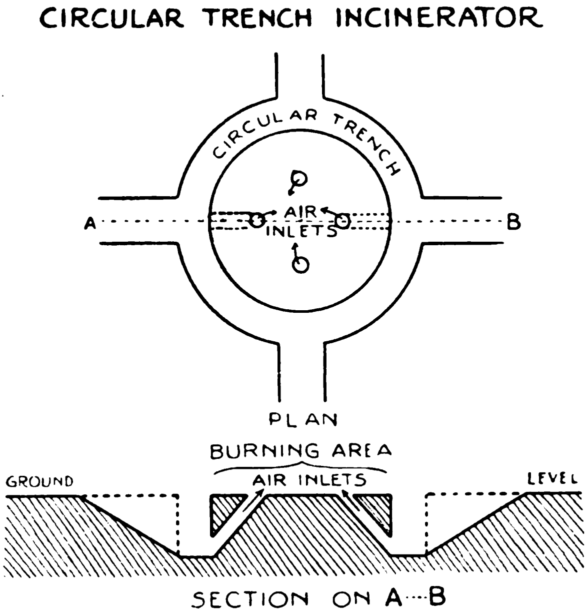

Fig. 49.

In the later stages of the war all such material was salved, bottles were separated from the refuse, tins had their solder extracted, paper was collected and sold, and grease was placed in barrels for the manufacture of soap or explosives.

The Disposal of Liquid Refuse.

The disposal of sullage from cook-houses and ablution benches was always a serious problem. Grease-choked drains and clogged soakage pits, and soapy water quickly decomposed and became very foul. As far as possible, soap scum and grease had consequently to be got rid of before the ultimate disposal of the liquid.

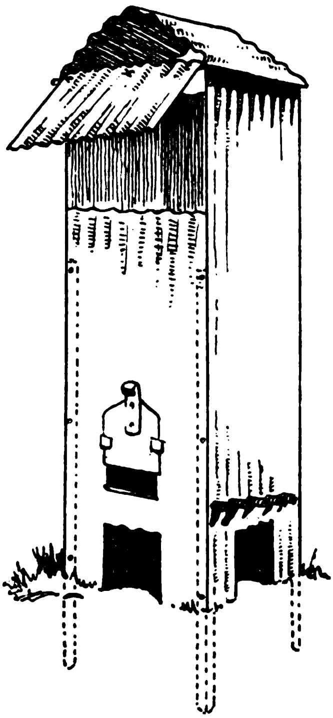

Fig. 50.—Corrugated iron portable incinerator.

Disposal of Grease.—All cook-house slopwater is rich in fat, and various forms of trap were used to free the effluent from grease. Such temporary measures of an improvised nature, as filtration through hay, straw or brushwood into an open soakage pit in the ground were the recognized methods of disposal of grease during peace manœuvres and in camps before the war, and traps of this description only were available for troops on the march. A perforated tin was placed over the soakage pit and filled with straw or brushwood, all greasy water was poured through this rough strainer, and a certain though limited quantity of grease was retained. Variations such as channels filled with brushwood or other material leading to the soakage pit were introduced (Fig. 51).

These grease traps were, however, inefficient, and there was an increasing tendency to give up using them.

Filters of sand, clinker and gravel were used with moderate success for the treatment of greasy and soapy water, but

where there was much water requiring treatment such filters rapidly became clogged and needed constant care and attention.

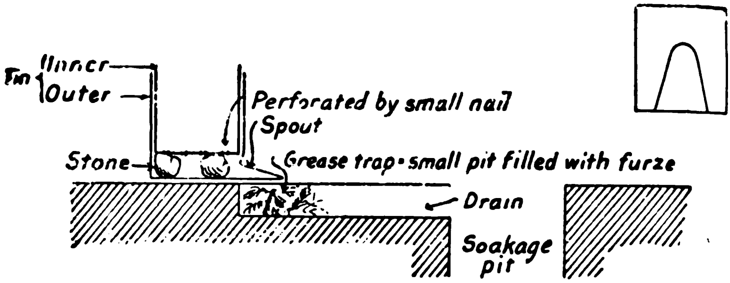

Fig. 51.—Grease trap for camps. (Inset showing method of cutting spout.)

Fig. 52 shows a grease trap with strainer and filter bed for sullage water. This method is suitable in places where ground is not absorbent. The strainer is made from bacon boxes and is perforated at the bottom. The hinges from a petrol box are used on the self-closing lid above the strainer. The petrol box is perforated at bottom, and contains hay or straw, which must be removed daily. To increase the efficiency chloride of lime should be added to waste water in the settling pit. This should be thoroughly mixed and allowed to remain overnight. The scum should be removed each morning. The chlorinated water passes through the wooden pipe and enters the filter bed close to the bottom. The water rises through the filter bed composed of rubble, medium rubble, gravel and sand and can be turned into any stream or ditch.

The best form of trap was that which depended upon cooling to remove the grease. If greasy water passes into a large volume of cold water, the grease solidifies and rises to the surface. By means of baffles it could, therefore, be retained in the trap and removed at regular intervals. The trap consisted of a cold water chamber holding from 100 to 250 gallons of water. One, two or more baffles were placed across the upper part of the chamber so as to hold back the grease, which rose to the surface. The water passed into the trap through a drain from the cook-house, or was poured directly in through some form of strainer. In determining the site for a grease trap it was necessary to decide upon the length of the drain from the cook-house. During the war grease traps were often wrongly placed; some were so close to the cook-house that the trap very quickly lost its effect through overheating of the water, some, on the other hand, were placed so far away that most of the solidification took place in the pipes. The trap should, therefore, be so placed that the maximum amount of cooling takes place, without solidification, before the liquid enters the trap; a suitable length of drain

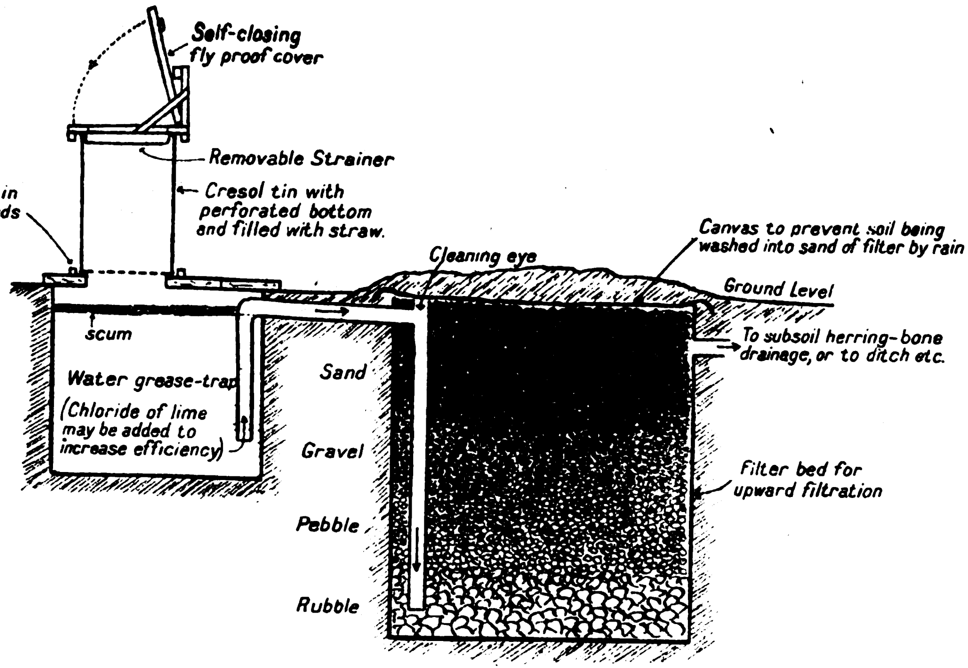

FIG. 52.

GREASE TRAP WITH STRAINER AND FILTER BED FOR SULLAGE WATER
(USEFUL IN NON-ABSORBENT GROUND).

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was found to be about 15 ft. With regard to the size of traps, a cook-house dealing with 100 men required a trap holding about 100 gallons of water, whilst for 600 men a trap holding from 250 to 300 gallons was suitable. Anything in excess of this required the traps to be duplicated, as it was inadvisable to have them of a large size.

A good type of trap commonly used in camps and field hospitals consisted of a rectangular receptacle with two baffles reaching to within four inches of the bottom ; it was made of tarred wood or of bricks set in and faced with cement. The pipes, both inlet and outlet, dipped a few inches below the surface of the water, and a wooden cover was provided (Fig. 53). With such a trap most of the retained grease was found in the middle compartment.

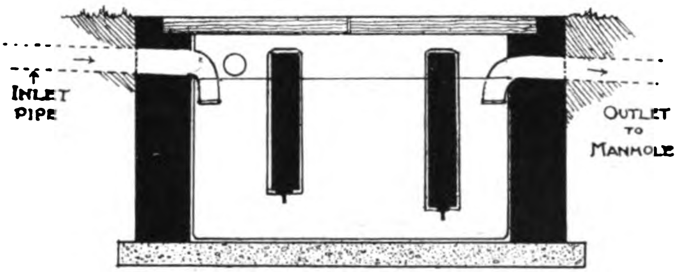

Fig. 53.—Cold water grease trap in brickwork or concrete. (Longitudinal section.)

A somewhat similar trap was one which allowed for filtration through fine clinker after passing through the water chamber.

Receptacles of every kind were employed to form grease traps. Three barrels (Fig. 54) communicating by pipes dipping well below the surface and set at various levels proved very effective, but it was necessary to bore a hole at the top of each pipe bend to prevent siphonage.

Three cresol drums have been used in the same way A large barrel with a baffle passing to within a few inches of the bottom also proved an effective trap.

Fig. 55 shows a simple grease trap easy to construct from materials available in all camps. It has proved efficient in actual practice, and has been in use for some time.

The materials required are half a wine barrel or stout box (preferably tin-lined), wood for cover, wire or leather for hinges, and jam or biscuit tins.

The traps are constructed as follows. Take half a barrel (or box) and cut a hole five inches from the top, and fit in jam tins as spout. Nail on a cover over one-third of the barrel, covering the spout. Hammer out flat a biscuit tin, and use it as a vertical partition, nailing it to the cover already in position

and to the sides to within four inches of the bottom of the barrel. Fix on the remaining two-thirds of the cover as a hinged lid. In this lid fix an open biscuit tin with perforated bottom. The tin should slope from the centre, as shown in the diagram. This enables all debris to be emptied into a pail receptacle when the hinged lid is thrown open.

Fill up the barrel and trap with water, and place hay or straw in the biscuit tin to arrest solid matter. The trap drains into a soak pit, or open drain if possible.

The kitchen water, grease and debris from the cook-house are emptied into the biscuit tin, solids are arrested, emptied as necessary, and burnt. The grease accumulates on the surface water on the open side of the trap and is periodically skimmed off.

The trap attends to itself, and requires only the supervision and cleaning inseparable from all improvised sanitary contrivances.

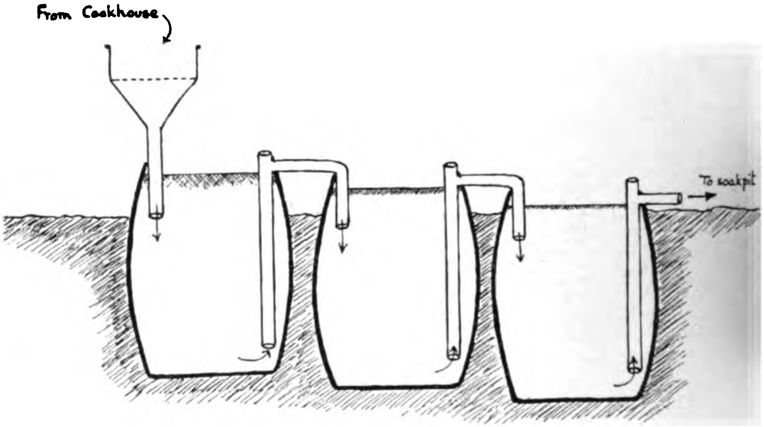

Fig. 54.—Diagram of a "three barrel" grease trap.

Derelict field sterilizing boxes were also used (Fig. 56).

Such cold water traps, when working properly, will hold back from 50–60 per cent. of the fat, and are quite effective enough to prevent choking of drains and clogging of soakage pits. A certain quantity of fat will always escape, and at times gives trouble to sewage disposal works.

The cold water grease trap possessed the great advantage that the fat could be collected and used for commercial purposes, a matter which was of great national importance and also a source of profit to the unit which owned the trap.

Innumerable variations of the cold water trap were designed; large traps and small traps, long traps and short traps; traps above the ground, traps below the ground; traps with many baffles, traps with few baffles; but all followed the same principle, and the more complicated they were the more ineffective and difficult to manage they were likely to become.

The question of baffles was always a vexed one, but there seemed to be little real advantage in multiplying them ; the grease rose in its passage through the trap, and provided there was a baffle near the exit there was no necessity for complicating the arrangements further, though a baffle placed near the entrance as well had the advantage of providing a middle chamber which would be undisturbed by the sudden inrush of hot water.

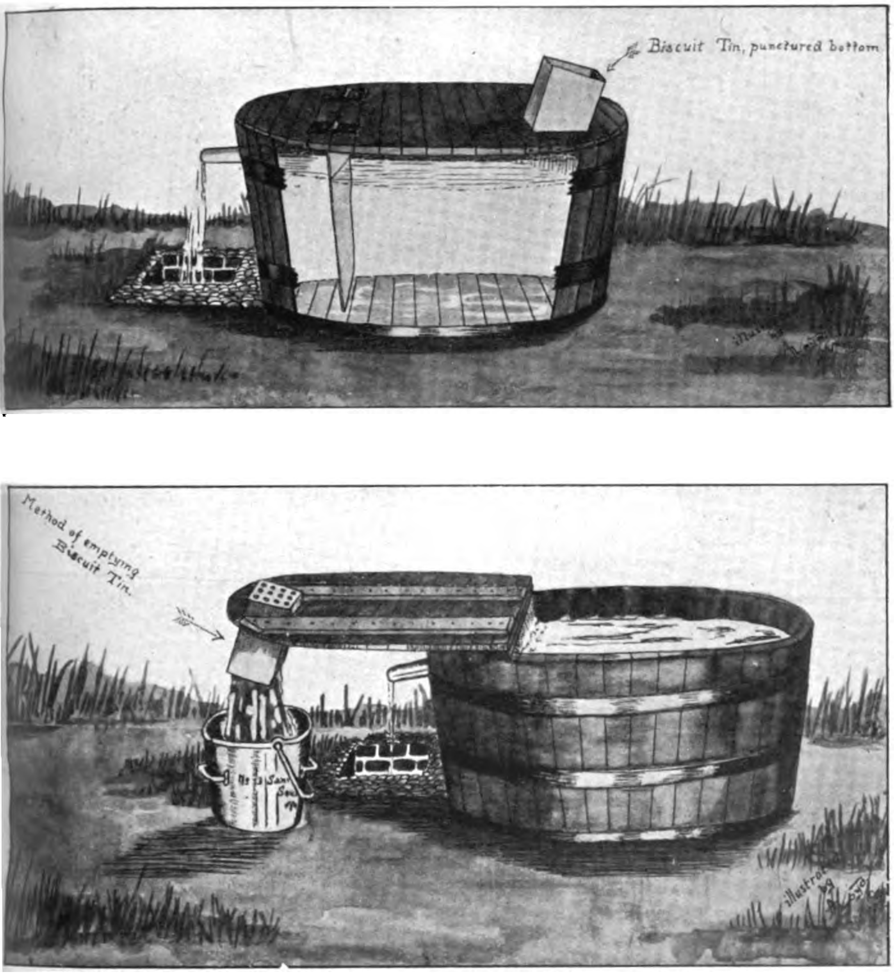

Fig. 55.

The disposal of soapy water from bath-houses and laundries was of considerable hygienic importance in view of the fact that such water readily decomposed and became a nuisance.

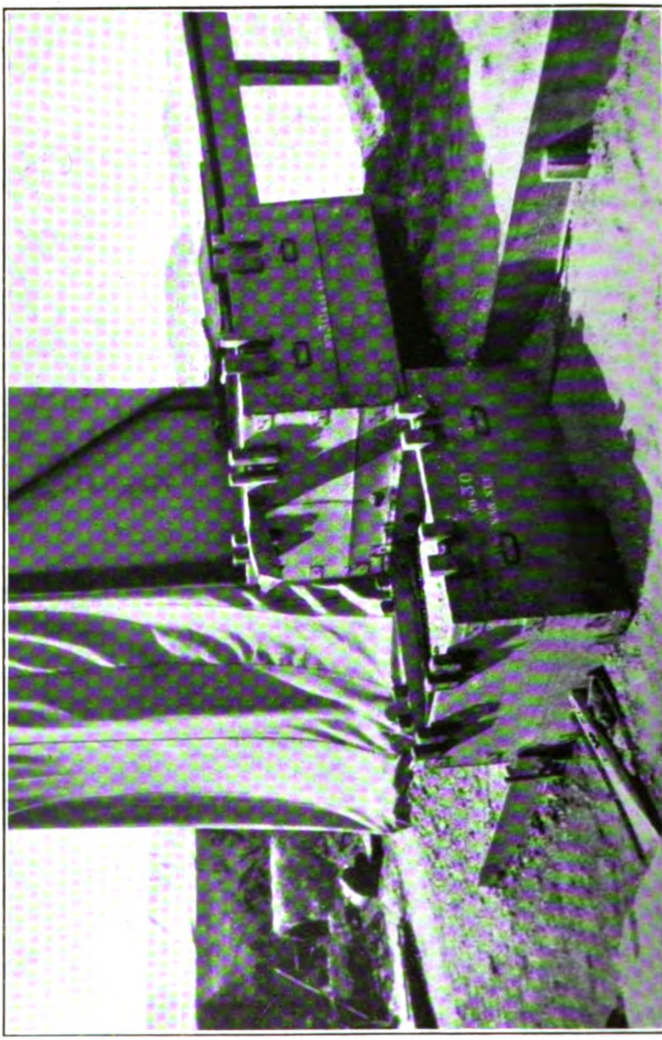

Fig. 56.—Field sterilizing boxes used as a grease trap.

Such waste water could be got rid of by water-carriage in natural water channels, such as streams or rivers; it could be passed into ditches or on to the surface of the land (Fig. 57);

or drained into soakage pits or, in the case of home camps, into properly constructed drains to a sewage disposal centre.

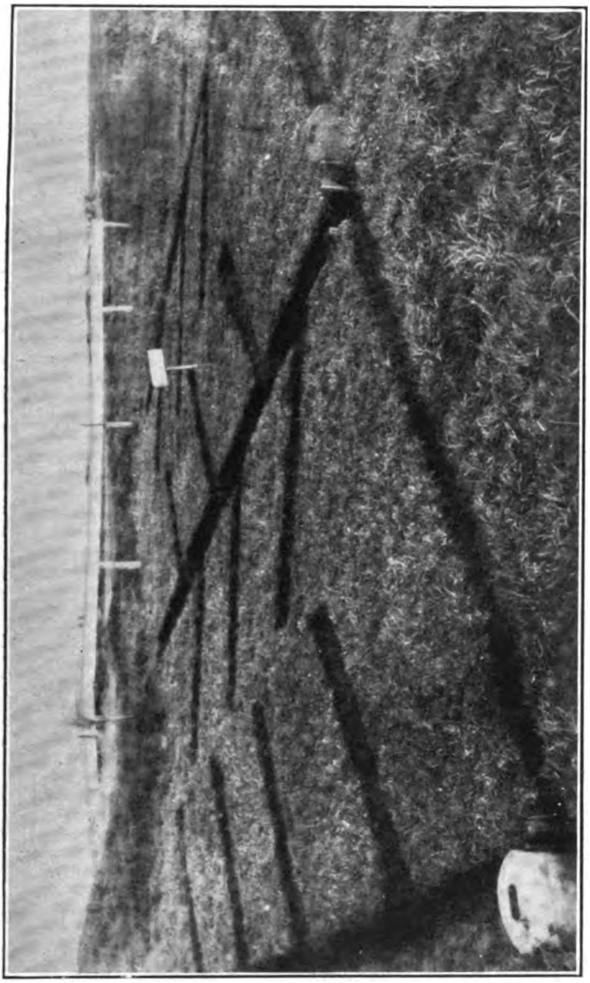

Fig. 57.—"Herring-bone" trenches for the disposal of waste water.

Under certain conditions passage into streams or rivers was harmless, but frequently the streams had to be used for watering horses or bathing, and any gross pollution was therefore undesirable. Surface disposal of untreated sullage water created a nuisance, and soakage pits were generally unable to dispose of the large volume of liquid.

It was imperative, therefore, to devise means for getting rid of the soapy scum and any sediment which might be present. Much could be accomplished by the use of an ordinary grease trap with subsequent filtration, but the finely suspended particles and colloidal matter still remained. To get rid of this colloidal matter an alum precipitating process was used.

It was generally sufficient to purify the ablution water by passing it through an ordinary grease trap with baffles, which held back the scum, and then through some rough form of filter made of clinker or fine road metal and gravel or sand. After this degree of purification it was found possible, in suitable soil, to dispose of large quantities of washing water into soakage pits, which were run on a twin system so as to provide intermittent periods of rest.

An ingenious system of disposal was devised, in place of using pits, by constructing long underground trenches running in the looser upper surface of the soil, the trenches being covered with pieces of wood or filled with tins and covered with old sacking and a little earth. With these trenches, preliminary passage through a baffle grease trap was found to be essential. Even with careful treatment in this way the effluent, more especially from laundries, was occasionally found to be too impure for satisfactory disposal, and treatment with bleaching powder was introduced by Lieut.-Colonel Beveridge, the A.D.M.S. (Sanitation) in France. A memorandum on the use of chloride of lime for the clarification of waste water from laundries, bath-houses and kitchens was issued, and also directions for ascertaining the amount of chloride of lime required (Appendices D, 1 and D, 2).

In December 1916 Lieut.-Colonel Monckton Copeman reported on the value of nitre cake for the clarification of waste water and pointed out that this substance was a waste product, of which 360,000 tons per annum were being produced at the time of the report. Unfortunately there were transport difficulties, as special vessels and railway trucks were required, and as a result nitre cake never came into general use.

Purification with bleaching powder also was little used at the front, and it was regarded as a measure reserved for special circumstances. But for laundries and large bath-houses it was of considerable value, and where there was a water shortage the process enabled the same water to be used over and over again, as was done in both Eastern and Western fronts. In a method devised by Captain Basil Hughes slaked lime was used instead of bleaching powder (Appendix D, 3).

On one occasion when the ground available for absorption was extremely limited, an alum precipitating process, with an automatic feed, was used in order to carry down the colloidal material.

These experiences laid the foundation of a system of treating ablution water in the field. It was, however, chiefly at the base, on the lines of communication, and in rest areas rather than in the actual front line that ablution water could be so treated.

CHAPTER XIII.

CONSERVANCY IN NORTH RUSSIA.

IN a latitude where for six months of the year the country was frost-bound, conservancy was a matter of extreme importance. The inhabitants, for the great part Russian peasants, were almost ignorant of any knowledge of sanitation. The small villages in which the troops were housed were in most cases grossly filthy. Further aggravation of the existing condition occurred at the end of the winter by the break of the frost. The gradual thaw of several feet of snow caused the country to become waterlogged, and the six months' accumulation of refuse and manure around the houses and in the village streets drained directly into the rivers or was left exposed to serve as breeding grounds for flies. Thus, in the early summer, when the pupæ of the preceding fly season had hatched out, the conditions from the sanitary point of view were at their worst.

Disposal of Excreta.—For descriptive purposes the latrine or closet accommodation as met with in North Russia may conveniently be classified under two main headings—that which was subject to some form of control, either by the local administrative body or as a result of the efforts of the individual owner, and that which was subject to no form of control whatever.

In the towns and larger villages, signs of the existence of a conservancy system were evident. The more substantial buildings had closet accommodation provided within; in other cases such provision was made in separate erections a short distance from the dwellings. Beneath the foundations of the house a large pit was dug, frequently considerably below the level of the subsoil water which in most parts of North Russia stood high. Over a portion of the mouth of the pit the closet was built and consisted of a box-seat and sometimes a wooden trough urinal. The remaining part of the mouth of the pit was external to the wall of the building and sealed by a heavy wooden cover, which, on being removed, permitted of access for clearing. When the accumulated fæces, urine, and waste water reached a height to within a foot or two of the surface of the ground, or when the smell became unduly offensive, the pit was emptied.

The interiors of the closets were as a rule commodious. Almost invariably they were suitably heated either by a stove situated within or by a stove which served in addition a contiguous dwelling room or passage. Occasionally the box-seat had a cover, but in spite of this a pungent sweetish odour, reminiscent of that from the deep narrow well-shaped closets frequently found in French houses, pervaded the apartment and frequently the adjacent passage. The apartment rarely was ventilated, although usually an effort had been made to ventilate the pit by carrying a wooden ventilating shaft from the mouth of the pit outside to the eaves of the house. In effect, this served the purpose of a soil-pipe, the air inlet being through the aperture in the box-seat. When present, the narrow wooden trough urinal was affixed to a side wall and fell towards the box seat into which the channel opened.

Ventilation of the closet and of the apartment did not present any great difficulty, provided a stove was situated conveniently. A small air inlet was placed over the door and an exit made into the flue of the stove. The pit was ventilated in addition to the external shaft by leading a similar shaft from the back of the box-seat across the roof of the apartment to communicate with the flue of the stove.

The emptying of the pits was undertaken, for example in Archangel, by the Vidange apparatus. One end of a length of wide hose-pipe was dropped into the pit; the proximal end was fixed by a screw attachment to a well-constructed barrel mounted on wheels or on runners, according to season, and drawn by a horse. By means of a strong suction pump, the barrel was exhausted of air, the sewage from the pit taking its place. The contents were thereafter deposited on the "tundra" at a considerable distance from the outskirts of the town.

Elsewhere, pits were emptied by direct pumping into impervious receptacles or, more crudely, by the use of pails attached to the end of ropes or poles. In winter, the contents of the receptacles in some cases were deposited in the adjacent river through holes cut in the overlying ice, or, with more expedition, actually on to the ice itself.

The closets of some houses were also to be found on the upper floors. From the seat to the underlying pit there was a drop of some 15 to 20 ft. and in winter it was no uncommon occurrence to discover a stalagmite 10 to 15 ft. in height, formed of frozen fæcal matter, which, in spring, was broken up and transported to fields, where the fragments thawed out later.

In the better class houses and larger buildings closets were flushed from small cisterns similar in type to those used where water-carriage systems are in operation. In such circumstances the cesspits became rapidly filled and required more frequent attention.

The villages, both large and small, rarely had any controlled conservancy system in operation. The inhabitants were responsible entirely for the disposal of excreta accumulating within their own curtilages. The result was almost too appalling for description. The latrine in many cases was situated in a small outhouse, often well-constructed, but frequently dilapidated, The closet had a small uncovered seat which gave access to a shallow trench below. Possibly from fear of louse or venereal infection, the Russian preferred to squat over the orifice after the fashion of the Indian native; the dejecta were not infrequently misdirected, with consequent gross fouling of the surrounding woodwork. Fæces adhered to the sides of the closet and became heaped up until the orifice was occluded. The latrine was then abandoned or removed to some other site, leaving the deposit more accessible as a breeding ground for flies in summer.

Occasionally this crude latrine was improved by the addition of a shallow box made to fit underneath the seat and to be moved when the time arrived for clearing.

At Murmansk, latrines were erected on the foreshore in many cases. A small pier was constructed at the end of which the closet was situated. There was a straight drop into the sea below. Thus the disposal was as complete as it could possibly be, but since at low tide the beach below the closet became uncovered the disadvantages were obvious.

In certain parts of the occupied area, rolling stock had to be used to provide additional accommodation for inhabitants as well as troops. Every type of long-distance carriage had its closet situated at one end—a type very similar in most respects to that used in British corridor carriages. In the fourth-class accommodation, the closet did not boast a pedestal seat. The passengers had to squat over a hole in the floor which communicated directly with the permanent way below.

Murmansk being the northern terminus of the railway connecting the Kola peninsula with Petrograd and the interior of Russia, a large amount of dilapidated rolling stock had accumulated there, almost all of which was used by refugees as dwellings. Conical piles of excreta were lying exposed under every carriage inhabited by Russian refugees. Such

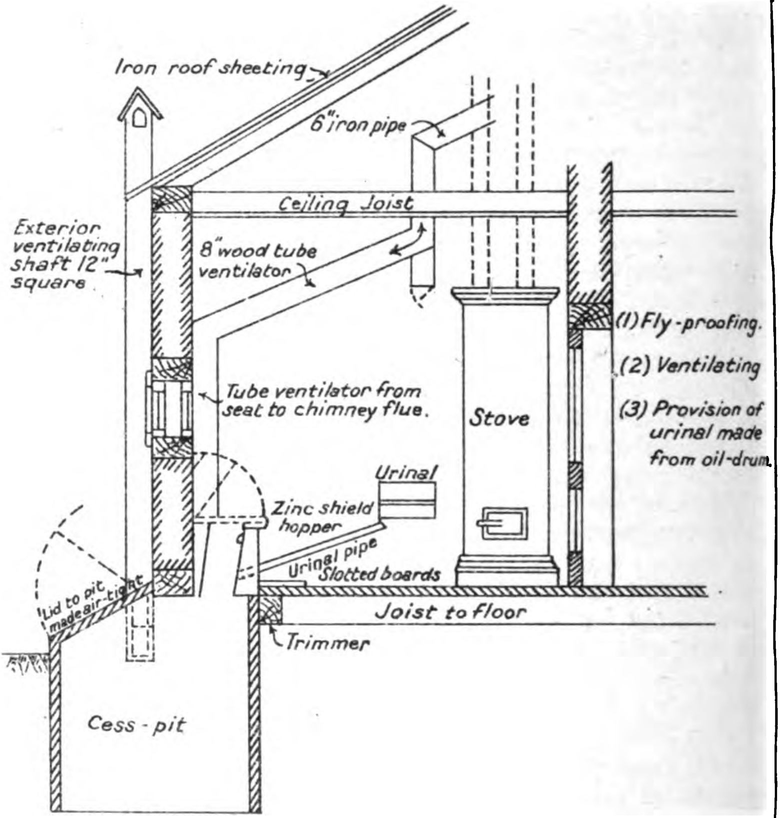

FIG. I.

METHOD OF IMPROVING SANITATION OF EXISTING RUSSIAN CESSPIT LATRINES.

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Malby & Sons Lith

were the conditions which met the original Expeditionary Force when it disembarked at Murmansk in June 1918—a fly season in full swing and an ever-increasing mass of uncovered excreta, the two prime factors in the production of an epidemic of infectious intestinal diseases. It was a matter of surprise, therefore, that no such epidemic occurred.

In the Archangel district, rolling stock was not used by the inhabitants, at any rate to anything like the same extent.

To an expeditionary force, with its full establishment of sanitary services, the problem of excreta disposal in a grossly insanitary country and under arctic or sub-arctic conditions would have been colossal. The small expedition—the nucleus of the comparatively large force which ultimately occupied this region—arrived and for many months continued to be so under-established in these respects as to be unable to attack quickly and efficiently even the most urgent of the prevailing conditions.

The bases at Archangel and its immediate suburbs and Murmansk were naturally the first portions of the occupied area to receive attention. The lines of action taken up were first to improve existing sanitary arrangements which appeared to be satisfactory, and secondly, to arrange for the incineration of excreta whenever possible.

The cesspit system in Archangel, although tending in summer to be offensive, was, of necessity, permitted to continue. Where, however, accommodation was available and particularly where a large number of troops was billeted, the bucket and incinerator system was established and the cesspits used only for the disposal of waste water. The emptying of the cesspits was directed by the local Russian Medical Officer of Health, with whom a most useful and excellent liaison was early established within a few days of the force's arrival in Archangel in August 1918. Nominally he remained in control of the system. Assistance was given him in the repair of the Vidange apparatus and in the supply of additional horses and forage, and the arrangements worked satisfactorily.

Care was taken that every cesspit and particularly those in connection with naval and military barracks were properly covered, fly-proofed and ventilated. Dilapidated wooden covers were repaired and replaced. The closets were supplied with self-closing lids. Metal-lined urinals were installed where necessary. That urine might not impinge upon the anterior portions of the seat, a metal protector was affixed to the interior of the closet seat. In nearly every case, the reconstruction was carried out by No. 125 Sanitary Section.

The cesspit system might well appear a crude and dangerous method of disposal, but practically it was one which responded satisfactorily to control. Where the Vidange apparatus was in use the disposal was no worse; indeed it was more efficient than that in some camps in England, where pail contents were emptied by local contractors into carts. The Vidange carts were thoroughly impervious, and if the emptying of the pits was under intelligent control, as it was by the sanitary section in Archangel, no soiling of the ground surrounding the cesspit outside occurred, nor did the Vidange cart leave a trail from the pits to the disposal ground. Flies did not appear to explore these cesspits either by way of the uncovered seat or through an imperfect outside cover. It is true that when the level of the pits' contents became unduly high the effluvium was objectionable and might easily have been a cause of ill-health, but regular evacuation of the cesspits both of the troops' billets and other dwellings was insisted upon. The clearing of the pits by pails was naturally prohibited, except in emergency, as by that method gross pollution of the ground around the cesspit and of the sides of the cart was unavoidable. The disposition of the sewage on the "tundra" was carried out at a sufficient distance from the town.

Where large billets were in occupation and the needs of comparatively large numbers of men had to be considered, additional latrine accommodation was provided. As far as possible this was required to conform to a standard pattern of latrine. Incineration of the fæces was demanded. Until latrine pails arrived from England, grease drums with handles riveted to the sides were used. Urine was prevented from gaining access to the fæcal pail by means of a small trough lying underneath the front of the seat and in front of and slightly below the upper edge of the pail. The trough fell towards the pail into which the urine was drained. The incinerator was fixed within the latrine which was, except on certain rare occasions, a well-constructed building, and served the double purpose of incinerating the fæcal contents of the pails and of warming the interior of the latrine. In addition, where possible, the incinerator was used for providing a supply of hot water. In several billets in Archangel and elsewhere, hot water was so provided.

On the lines of communication and in the forward areas, suitable buildings in which to instal such latrines were not always available, and special arrangements had to be made. In this respect, due consideration had to be given to the

peculiar conditions under which the force operated. Materials for construction were not plentiful locally; consignments from England were delayed in arriving on account of the ice-bound state of the White Sea and the Dvina River; the lines of communication were long and sleigh transport facilities inadequate for large quantities of heavy stores. Units on lines of communication and forward areas, therefore, at first had to make their own arrangements for sewage disposal. Here again further difficulties were encountered. The nature of the operations demanded the distribution of the force into detachments which occupied the different villages on the lines of communication and in the forward areas. The force had one Specialist Sanitary Officer who was D.A.D.M.S. (Sanitation), but who had to devote a large amount of his time in assisting in the administration of the medical, as distinct from the sanitary, service. To undertake an inspection of the forward areas, this officer would have had to be absent from General Headquarters for six weeks or two months, during which time central control must, under the existing circumstances, have been relaxed or lost.

For executive work there was one sanitary section. Its activities extended for the first eight months of the campaign no farther than the base and the villages and ports immediately adjacent to the base.

The lines of communication could not then have any direct assistance from a sanitary section. Definite instructions, however, were issued from General Headquarters early in the campaign regarding the most practical methods for the proper sanitation of the billets. Empty grease drums were made use of and modified so as to provide fæcal pails, urine pails and excreta incinerators. Illustrated directions for their modification were forwarded to all detachments. Later, units were provided with fæcal pails, and incinerators improvised at the base were distributed to forward areas. These were made use of to a great extent, but in many instances apathy, or perhaps rather general fatigue and depression, defeated much of the sanitary effort directed from General Headquarters.

It was not possible at all times to obtain active assistance in constructional sanitary work from the Royal Engineers, as their services were already overtaxed in preparing defences and erecting hutments. Consequently much of the work was given out in contract to local engineering firms, such contracts being usually arranged by the officer commanding the sanitary section and the work carried out under his supervision. At the

base and its immediate environs full use was made of these facilities, but it was not possible to extend them to the more distant parts of the occupied area. Later, however, a large quantity of sanitary material, such as incinerators, was in this way improvised for distribution to distant detachments.

Material invaluable for sanitary services was discovered at the Vodke Store in Archangel, notably, iron vodke drums of varying sizes. These were remodelled by the sanitary section into effective excreta incinerators and distributed throughout the force in comparatively large numbers.

In some of the villages in the forward areas the existing Russian sanitary arrangements were so elementary as not to boast even of the crudest form of latrine. Fæces were deposited in the barns which formed parts of the actual dwellings.

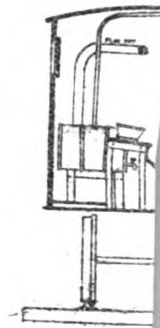
The barns usually formed part of the ground floor of the dwelling, the upper portion being the living and sleeping quarters. The ceiling of the barn communicated immediately with the apartments above by means of a circular hole over which the inmates defæcated. Where such conveniences existed the "hole in the floor" was effectively sealed and fly-proof latrines constructed for civilian use. Public latrines were built at different points on the railway lines and on the sleigh routes and were maintained in a reasonably sanitary state.

A certain portion of the force was operating on the railway and was accommodated in rolling stock. Special latrine provision was therefore made, and a special latrine train was improvised at the base and dispatched on completion to the railway force.

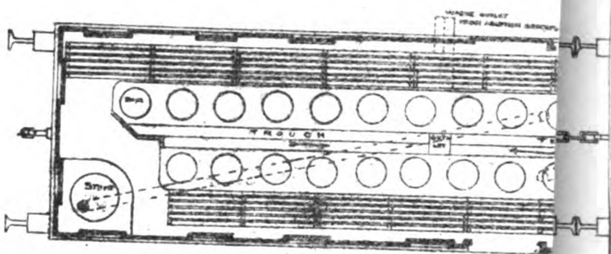
The plans were devised at General Headquarters and the sanitary section undertook the necessary constructional work. Sufficient rolling stock was obtainable with which to form a complete "sanitary train" containing ablution, latrine and incinerator coaches. The train consisted of seven coaches, each being 20 ft. in length with the exception of two American freight wagons 40 ft. in length. The coaches were arranged so as to occupy the following permanent relative positions:—

Coach 1.—Other ranks latrine.
,, 2.—Officers' latrine and incinerator.
,, 3.—Store wagon.
,, 4.—Living wagon.
,, 5.—Ablution.
,, 6.—Dressing room.
,, 7.—Bathing.

In addition, the train had a disused locomotive, incapable of moving on its own steam, and two water tank cars. These



TRANSVERSE S



ABLUTION WAGO

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rmed a detachable section of the train which could be taken
 one of the locomotives in action to a water point on the
ie for refilling. Hence this portion was kept at the rear of
e train.

Coach 1 was 40 ft. in length and accommodated 32 fæcal
ils under fly-proofed seats and 6 urine pails. Duck-board
ances were provided and a stove placed at each end, the flue
pes being carried down the length of the wagon to emerge
idway through the roof.

Coach 2, which was in part an officers' latrine, was divided
ito two distinct portions. One contained six seats, similar to
hose in coach 1, whilst in the other portion a vodke drum
ncinerator was installed for the destruction of the contents of
he fæcal pails. To prevent overheating of the wooden walls of
he coach a protective lining of corrugated iron was fixed.

Coach 3 was simply a store wagon in which to keep all
rdnance and other supplies used in connection with the
aily working of the train.

Coach 4 was bunked to give sleeping accommodation to six
ien detailed to keep the train in working order.

Coach 5 was 40 ft. in length and adapted so that twenty-
ine men could wash at once. The wagon was 9 ft. in width
nd a bench 5 ft. in width was placed in the middle. Running
lown the centre of the bench was a deep galvanized iron trough
eading to a waste water pipe which could be carried into a
onvenient ditch or soakage pit. Bowls and duck-board
stances were provided. At one end of the wagon, two fifty-
gallon iron tanks were fitted up, one to act as a cold water
supply and the other to give hot water. These tanks in turn
received their supplies through a hand pump from large barrels
placed immediately outside the wagon on the permanent way.
The barrels were filled by hand from the large water tank car in
the detachable portion of the train. A steam pipe was carried
from the locomotive in the detachable section to one of the
tanks in this wagon and in this way hot water was readily
supplied. Each man filled his own bowl with hot and cold
water from the tanks which were provided with draw-off
taps. This wagon also contained stoves.

Coach 6 was suitably warmed and provided with seats,
pegs for clothes and pigeon-holes for boots. By means of a
small intercommunicating corridor access to coach 7 was
possible, where there were twelve wooden baths made from
barrels. Water tanks were installed and one was heated by
steam from the engine. The water was pumped to the tanks

from the water tank car which was the next wagon and the first part of the detachable section.

The train fully supplied the needs of a battalion. It was found that a staff of six men was sufficient to keep the train working efficiently, and so long as they remained undisturbed the arrangements proved excellent.

Several types of incinerator were in use throughout the force. The Horsfall pattern, constructed in brick when this commodity was available was frequently adopted. Russian contractors became dexterous in erecting these when guided by definite plans.

Experience showed that the Canadian stove was of great value as an excreta incinerator for small outposts. The combustion though slow was perfect and unaccompanied by any disagreeable smell. The bottom of the interior of the stove was filled with ration tins to a point slightly above the lower opening of the air inlet pipe to avoid any obstruction by the fæces to the incoming air. Iron vodke drums were converted into incinerators of this nature. The small Russian stoves, which are tin boxes lined with brick, were similarly transformed, with an air inlet similar to that of the Canadian stove. Oil drums were also used. There was usually little difficulty in making a good incinerating mixture; wood chips in nearly every case were available and could be incorporated with the fæces.

The disposal of urine was an infinitely more difficult problem. Where the cesspit system was in operation the urine found its way eventually to the "tundra" in the Vidange carts. In other cases it was deposited in pits dug in the soil and subsequently covered. Only in exceptional circumstances was it possible to make use of a soakage pit, for rarely was any soil discovered in the occupied area which would deal with urine in this way; the soil generally was waterlogged. Elaborate arrangements for sterilizing the urine by passage through sawdust were impossible owing to there being an insufficient quantity of the necessary material. The most that could be done consisted in adding to the urine and fæces enough cresol solution to inhibit the growth of pathogenic organisms, and this was actually carried out.

Disposal of Waste Water.—In Archangel and the adjacent suburbs, the cesspits received waste water in addition to excreta. Modern wash-hand basins, baths or sinks discharged their contents into cesspits which were emptied by the Vidange carts. Elsewhere, as in small villages, waste water was cast

from the dwelling straight into the street or into the enclosure. This was the only method the Russian peasant understood.

From the military hygiene standpoint, the provision of suitable means for disposal presented great and unusual difficulties. No satisfactory arrangement could be made. A waterlogged soil precluded the use of soakage pits.

Gross solids were removed from waste water by means of strainers improvised from biscuit tins and the fluid deposited in a pit and immediately covered. Waste water thus strained was led to the river through surface drains.

Disposal of Refuse.—Except in the forward area and on portions of the lines of communication the disposal of refuse was comparatively easily arranged for.

The system favoured by the Russians consisted of a large wooden erection not unlike a coal-bunker which was commonly to be found in a portion of the yard of the house. The refuse and kitchen garbage were tipped into the receptacle through a hole in the roof supplied with a sliding cover. Periodic visits were made by carts or sleighs to empty these refuse bins, the refuse being conveyed to the " tundra " some distance from the village or town. In practice, however, the removal of refuse did not take place sufficiently often, so that it was scattered indiscriminately round the already completely filled receptacles.

In villages, the refuse from the houses was deposited in any convenient spot, most commonly in the street or yard, to become in summer a breeding place for flies.

Arrangements were made in Archangel for the collection of refuse from all billets and from certain of the inhabitants' dwellings. An incinerator was erected at a point as nearly as possible central in the town. The destructor conformed to the Horsfall pattern and was built in brick and enclosed in a well-constructed building allowing accommodation for a staff of two Russian workmen and a large area in which to tip the refuse. Special dust carts and dust sleighs were built. They were metal-lined and were provided with impervious fly-proof covers and a special sliding panel at the back to facilitate the removal of the contents at the destructor. The dust carts or sleighs visited the billets in the town several times weekly and removed the refuse from the covered bins with which each billet was supplied. The entire scavenging system, as organized by the officer commanding the sanitary section, was undertaken by locally enlisted Russian labour, whilst the destructor was erected by the personnel of the section.

Similar arrangements were made and satisfactorily carried out at Solombola, Bakharitza, Economie, Isako-Gorka and Obozerkaia.

At small posts, such as relay posts on the sleigh routes on the lines of communication, each day's accumulation of refuse was burned in the cook-house fires. Later in the campaign the central conservancy system was adopted in all villages where troops were housed.

In January 1919, Sanitary Standing Orders were compiled having particular reference to the force and the peculiar climatic conditions and unusual circumstances under which the troops had to operate. These were printed in Archangel by Russian compositors and the sanitary section prepared diagrams of apparatus and improvisations of available material especially suitable to meet the local conditions.

CHAPTER XIV.

THE HOUSING OF THE SOLDIER.

THE buildings, barracks, huts, tents and other shelter, which constituted what may be called generally the housing of the soldier during the war, were as varied as the climates and countries in which he served and the nature of the warfare in which he was engaged. It is convenient therefore to consider these various conditions under the headings of the countries concerned; but where the housing demanded the preparation of special plans and constructions these were generally worked out by the authorities at the War Office, irrespective of the country or climate to which they referred. This was specially so as regards plans of hospital constructions.

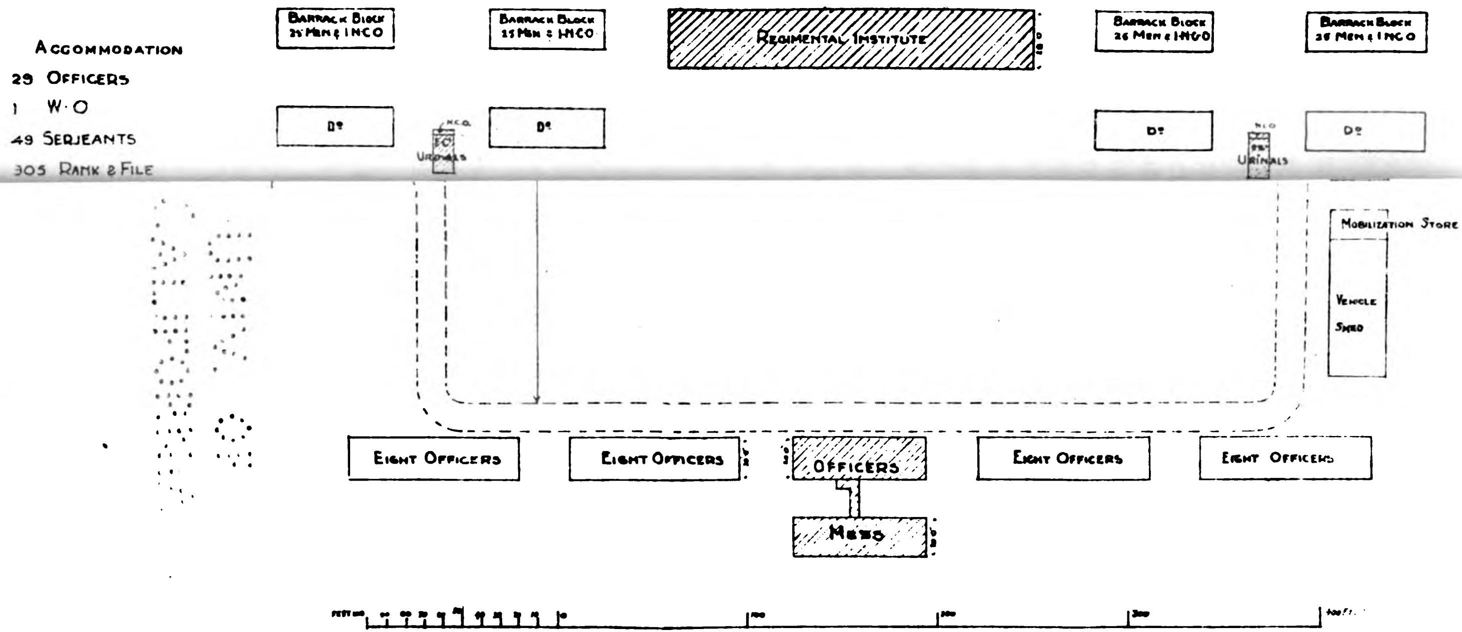
IN THE UNITED KINGDOM.

Immediately after the declaration of war the housing of soldiers at home became a pressing problem. On 11th August, 1914, it was decided to form six divisions of the First New Army to replace those which had gone abroad and to concentrate them at certain training centres; these were Aldershot, the Curragh, Salisbury, Shorncliffe, and Colchester. Existing barrack accommodation was used to the utmost, but it was insufficient for divisions at war strength, and many troops were at first housed in tents. Huts were ordered to be erected so as to make up the deficiency in accommodation. A new training centre was also formed at Grantham, and hut accommodation for an entire division had to be built. Infantry depôts were enlarged by the addition of huts, so as to bring the total accommodation to 1,000 men. In connection with this scheme of hutting, type plans were prepared at the War Office. From a hygienic point of view it was most important to secure sufficient floor and cubic space, and, above all, wall space for each soldier, and it was hoped that the standards established after the Crimean war, namely, 600 cub. ft. per man, and 3 ft. between the beds, might be followed. On 14th August, 1914, an Army Council letter was addressed to all commands, in which it was stated that owing to the urgent necessity of accommodating the troops so that they might be concentrated for training purposes, it was imperative that the existing barrack accommodation should be taxed to the

full, and for this purpose the cubic space per man in barrack rooms might be reduced if necessary to 400 cub. ft., instead of the existing scale of 600, but this reduction was only to be resorted to in case of absolute necessity when other means of providing accommodation in barracks failed. In order to ensure that the principles of hygiene were not violated and that the health of the troops would not suffer where this course was necessitated, the windows of barrack rooms were to be so fixed that they would remain open permanently to whatever extent was considered necessary. Unfortunately, owing to the large amount of work to be done and the pressing need of housing the troops before the winter months, and for financial reasons, the military authorities were compelled to adopt generally 40 sq. ft. of floor space and 400 cub. ft. for each man. On 8th December, 1915, a further letter was addressed by the Army Council to commands calling attention to the importance of avoiding overcrowding, whether men were accommodated in barracks, hired buildings, or billets. The superficial space allowed to each man by regulation for sleeping quarters was 40 sq. ft., and the greatest care was to be taken that not less than that allowance was provided in every case. If it was found that the number of men in occupation exceeded the accommodation reckoned on that basis, immediate steps were to be taken to remove a sufficient number to bring the accommodation within the regulated scale. The men so displaced might, according to circumstances, be accommodated in any public quarters, hired buildings, or billets, which might be available, or might be placed under canvas; but if this latter course were adopted, the tents were to be supplied with tent bottoms and pitched on well drained ground close to existing dining and recreation rooms, so that the tents might be used for sleeping only.

The standard hut designed by the Royal Engineers was 60 ft. by 20 ft., allowing for each man 4 ft. of wall space. This meant that between two beds there would be only 18 in., instead of 3 ft., as allowed in the normal peace designs. In the type plan for an infantry regiment (Fig. 1) the sergeants' mess, dining rooms, drying rooms, bath-rooms and regimental institute were arranged down the centre of the camp space and the men's living huts on each side. Between the rows of living huts were the latrines, urinals and ablution rooms. The original intention in this planning was to provide no sleeping huts at all at first, but only accessories, the officers and men sleeping in tents with boarded floors. By building on

Standing Camp for One Battalion of Infantry – War Strength –



Scale R.F. $\frac{1}{600}$

FIG. I.

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this plan the men would have had their tents pitched on the sites of the sleeping huts, so that, if at a later period, these huts were authorized, they could be built without disturbing the general plan. It was thought that in the very limited time available before winter no more than this should be attempted. The Army Council, however, acting on medical advice, decided that huts for sleeping should also be built. The adequate ventilation of sleeping huts, a matter of the first importance owing to the proximity of the beds, proved somewhat difficult. Experience in peace time had proved that the only adequate method of ventilating barracks and huts was by means of open windows, arranged so as to prevent a down draught on the sleeping men. Under strict discipline with efficient officers and N.C.Os., such a system was found practicable in peace time. But experience soon showed that with the new armies this was impossible; men would shut the windows at night time, and officers and N.C.Os. could not be depended upon to prevent this practice. The Director of Fortifications and Works suggested that numerous holes should be bored in the gable ends of the huts; this improved matters, but did not provide sufficient ventilation. Louvred ventilators, 3 ft. by 2 ft., in the gables, combined with ventilating shafts in the ridge of the hut, were then tried; finally, a strip of boarding was removed from under the eaves on both sides of the hut, the aperture so provided being protected by boards set at an angle so as to prevent direct draught on to the men. This, combined with windows protected with side pieces at either end of the hut, proved the most efficient method of ventilation.

The men's huts were planned to accommodate either 25 or 30, with a floor space of 40 sq. ft. per man. In the dining-rooms, 7 sq. ft. per man were given, it being assumed that only 80 per cent. of the men would dine at one time. In the regimental institute there were a supper room 100 ft. by 28 ft., a games room 50 ft. by 28 ft., and a corporals' room 48 ft. by 28 ft. Between the supper room and the corporals' room there was a refreshment room, where food and drink, including malt liquors, were served. Drying rooms were designed, so that as many wet coats as possible could be hung from bars slung from the trusses. Heat was supplied by stoves, air-ducts were provided, the floors were of concrete cemented to the outfalls, and the interior was lined with asbestos sheets so as to conserve the heat. With two stoves the wet clothing of about 250 men could be dried

in a room 20 ft. by 20 ft. Bath-houses were arranged on the shower and foot principle, the allowance being 4 per cent. of the strength of the unit. Each bath was 2 ft. 6 in. square, and about 8 in. deep, with a shower above. For a battalion of infantry, or corresponding unit of another arm, officers' quarters were provided. These generally consisted of huts containing eight rooms, each 16 ft. by 10 ft., one for each officer above the rank of captain, or for two captains and officers of junior ranks. The officers' mess and ante-room was of the simplest character, situated in the centre of the row of officers' huts with a kitchen behind. The officers' mess and quarters were separated normally from the men's huts by an open space for parades. On one side of this were the regimental offices and guard-room, and on the other side the vehicle sheds, stables and mobilization store.

In September 1914, orders were given to prepare huts for the Dominion troops, about 60,000 men, on Salisbury Plain. The hut accommodation was to be on the scale of that of the First New Army. Early in the same month orders were also given for raising the Second and Third New Armies, each of six divisions, and also to provide at all the defended ports shelter huts, supplementary to the barracks available, for about 120,000 men, mainly belonging to the special reserve, but also to the Fourth New Army.

This enormous increase of the hutting scheme necessitated a complete revision of the planning, and the Army Council were of opinion that in order to reduce the cost, as far as possible, everything should be omitted that could not be regarded as an absolute necessity in respect of shelter from the weather. The original plans were revised and a cheap type of hut shelter was designed. Towards the end of September and in October 1914, orders were given to provide huts for the Ulster Division in the North of Ireland, and for the locally raised corps of about 80,000 men, chiefly in large cities, forming the Fifth New Army.

Later in the year the Secretary of State for War gave orders for the selection of new training centres in the North of England, with huts for two divisions each at Richmond (Yorkshire), Ripon and Cannock Chase, and for one division each at Clipstowe, Prees Heath, Whitchurch and Rhyl.

The huts for the First New Army were made with corrugated iron walls and roofs, with asbestos lining. In the Second, Third, and subsequent Armies, this type of construction was confined to accessory buildings, and the sleeping huts were built of

weather boarding and felt roofs. At first these had no lining, but subsequently this was added, as owing to the warping of new timber the huts were not weather-proof.

As already mentioned, the huts for the First New Army were 60 ft. by 20 ft., but the " shelter huts " subsequently provided were not so wide, measuring 60 ft. by 15 ft. They had the advantage of providing more wall space, namely, 5 ft., when the allowance of 40 sq. ft. floor space per man was maintained. When these narrow huts were built it was necessary to provide dining rooms, and this, from the medical point of view, was another advantage. In many of the hutted camps containing 60 ft. by 20 ft. huts, dining rooms were not built until a later period.

At Richmond in Yorkshire, the huts occupied by the troops were standard 60 ft. by 20 ft., but of different types of construction, one type having solid Portland cement blocks between steel stanchions, and the other walls formed on steel framing with Portland cement plaster on expanded metal on the outside, and lime plaster on lathing on the inside. Roofs were of asbestos tiling or slates. The Army Sanitary Committee considered these huts to be far superior to those of wood or galvanized iron. They were cool in summer and warm and dry in the winter.

Unfortunately, the winter of 1914-15 was unusually wet and, in order to give the troops protection from the inclement weather, camps were occupied as soon as the huts had been built, and before proper roads and paths had been constructed. The result was almost disastrous ; in some camps men constantly waded through seas of mud, and the conditions were almost as bad as those in the trenches overseas. On Salisbury Plain, too, an outbreak of cerebro-spinal fever occurred amongst the Canadian troops in Bulford Camp, and the conditions then obtaining necessitated the camp being evacuated until roads could be constructed.

From the point of view of health and comfort it would have been wiser to have let the troops remain under canvas until the hutted camps were completed. Experience overseas showed that even circular tents with boarded floors could be occupied during the winter months without any detriment to health, and in exposed situations the troops would have been far more comfortable in large tents with boarded floors, and warmed by stoves, than in the hutment shelters without lining. But, as the war was likely to be of long duration, it was a wise policy to erect huts. Tents were not durable, and their upkeep was costly.

In spite of all the work carried out by contractors under the supervision of the Royal Engineers, billets had to be provided on a large scale at various parts of the kingdom during 1914 and 1915. In the Aldershot Command 22,400, in the Eastern Command 320,000, in the Northern Command 102,000, in the Western Command 100,000, and in the Scottish Command, 48,000 billets were provided between August 1914 and January 1915.

Previous to the war billeting on a large scale was practically unknown, and billets were mainly used for troops on the march to manœuvres or camps of exercise, and the occupation was for very short periods. With the advent of war, when many thousands of troops had to be quartered, otherwise than in barracks or huts and often for considerable periods, new problems arose, and quartering regulations were issued in 1915.* Revised regulations were issued with Army Orders dated 1st June 1917, and the methods of quartering troops in these regulations were arranged in four distinct groups: (1) hiring buildings under formal agreement; (2) taking possession of buildings under the Defence of the Realm Regulations; (3) occupying schools, poor law institutions, asylum buildings, railway property, etc., by arrangement with the Government departments, local authorities, and railway companies concerned; (4) billeting, which might be either for accommodation only or for accommodation and subsistence. Billeting was ordered to be avoided as much as possible, and unoccupied buildings were to be utilized in preference to others, and to be taken by agreement, or under the Defence of the Realm Regulations and not under billeting notices. In occupation for long periods endeavours were always to be made to hire large buildings, rather than billet troops in private dwelling houses.

Houses of substantial householders were first to be utilized and poorer districts avoided. In dwelling houses not more than one man to every two rooms was to be allotted. In all billets in large buildings a minimum of 40 super. feet and 400 cub. ft. of space for each man's sleeping quarters was to be secured. Billets for officers were not to be in the same building as those for the men, but were to be provided conveniently near. Billeting with subsistence proved to be a costly arrangement, and it was found preferable to accommodate troops in hired houses with central messing. In cases where hired houses were not obtainable in sufficient numbers,

* Army Order 448.

troops were consequently billeted without subsistence and a building was hired for central messing.

In the early days of the war many unsatisfactory billets were provided by the police, and in view of the insanitary condition of many of the premises it was decided that the chief officers of the police should consult the medical officer of health of the town or district before proceeding to allot billets.

Later on, each command in the United Kingdom was divided up into definite quartering areas for each of which an army quartering committee was appointed. Area quartering committees working under the direction of the army committee were also formed. Each area committee was ordered to keep a schedule of all accommodation suitable for troops, and hospitals. The number of available billets was to be obtained from the chief of the police. A list of premises available for hiring was also to be compiled in consultation with the local police and rating authorities. Remarks as to water supply and other sanitary conditions were to be added. As a R.E. officer and a sanitary officer were on the area committee it was possible to have all houses and buildings likely to be used by troops properly surveyed before occupation and an estimate made of the structural work required to make them habitable. Usually the work related to the provision of better ventilation and more latrine and lavatory accommodation. Where troops were billeted in large numbers and there was an insufficiency of kitchen accommodation, field kitchens were constructed. If latrine accommodation was insufficient field latrines were ordered to be constructed in convenient places up to a scale of four seats per 100 men. Proper sanitary arrangements were made with the local authorities for removal of excreta and urine, but where possible it was found better to construct trough latrines for the troops, the sanitary authority making the necessary sewer connection.

Early in 1917 owing to the shortage of timber and the cost of construction, the Director of Fortifications and Works suggested reducing the floor space in barracks and huts to 30 sq. ft. Also in connection with the new hutting for the Royal Air Force a similar suggestion was made. The army medical authorities protested against this reduction, pointing out that in the 60 ft. by 20 ft. hut the beds would practically touch one another and the danger of droplet infections would be greatly increased. It was considered that such a reduction should not be sanctioned except in the most urgent necessity and then only in the 60 ft. by 15 ft. huts, where a wall space of

4 ft. could still be obtained. The outbreak of influenza in 1917, with its attendant dangers of infection, caused the proposal to be dropped.

In February 1917 when women were employed in place of men in cooking and domestic work in regimental institutes and in hospitals a scale of accommodation in hutments was drawn up for them. Lady superintendents were given a sitting-room 120 sq. ft., bedroom 120 sq. ft., bath-room and w.c., and head cooks and head waitresses, one bedroom for two persons, 160 sq. ft.; a common sitting room or mess room, about 12 sq. ft. for each person with a minimum allowance of 150 sq. ft., was allowed; cooks, waitresses and housemaids were accommodated in dormitories to hold six persons, 60 sq. ft. for each, with a common room as above.

In July 1917, this accommodation was modified for members of the W.A.A.C. An administrator had the same allowance as a lady superintendent, but the forewomen were placed in small cubicles, 65 to 75 sq. ft. being allowed for each, and women workers in dormitories without cubicles, 50 sq. ft. being allowed for each person.

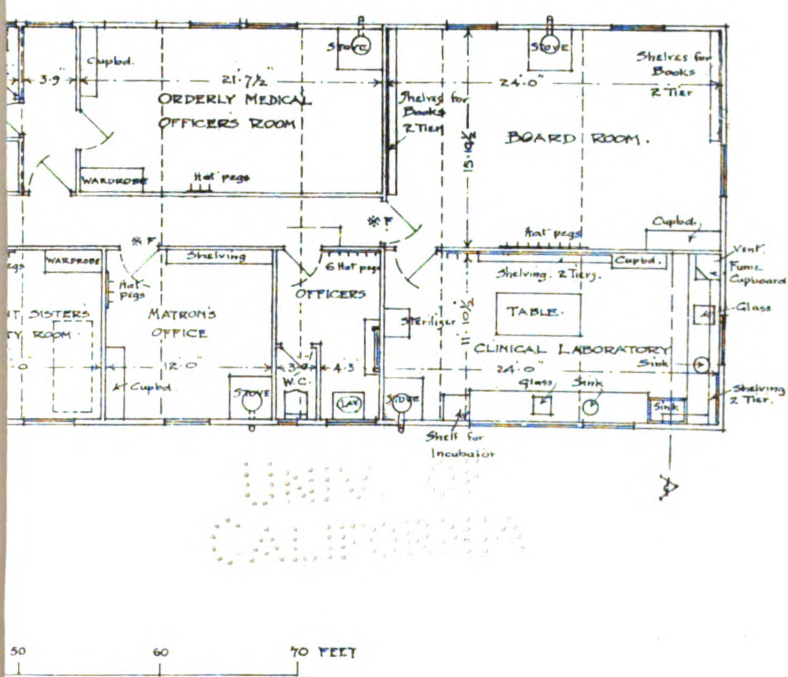
Hospitals.

The formation of hospitals and extent of hospital accommodation in the United Kingdom are described in Chapter V of the first volume of the General History of the Medical Services.

For the hutted hospitals erected by the War Office at various military centres, a standard design was prepared in the Directorate of Fortifications and Works at the War Office and issued to various commands. The first design, prepared in 1914, was in four sections: (*a*) quarters for the R.A.M.C.; (*b*) quarters for the female staff, (*c*) administrative offices, operation blocks; (*d*) wards.

The design for the quarters of the R.A.M.C. was the same as that of the battalion type, except that bath-rooms were provided in the officers' huts. The quarters for matron and nurses were much the same as ordinary officers' quarters. Two nurses occupied a room 16 ft. by 10 ft.; the matron had a separate bedroom and sitting room. The administrative offices contained medical officer's office, registrar's office, clerks' offices, matron's office, nurses' night duty room, orderly medical officer's room with bath, board room, clinical laboratory, dispensary, waiting room and consulting room, and a lavatory for men and another for officers (Fig. 2). The operation block contained an operation room with a large north window, a

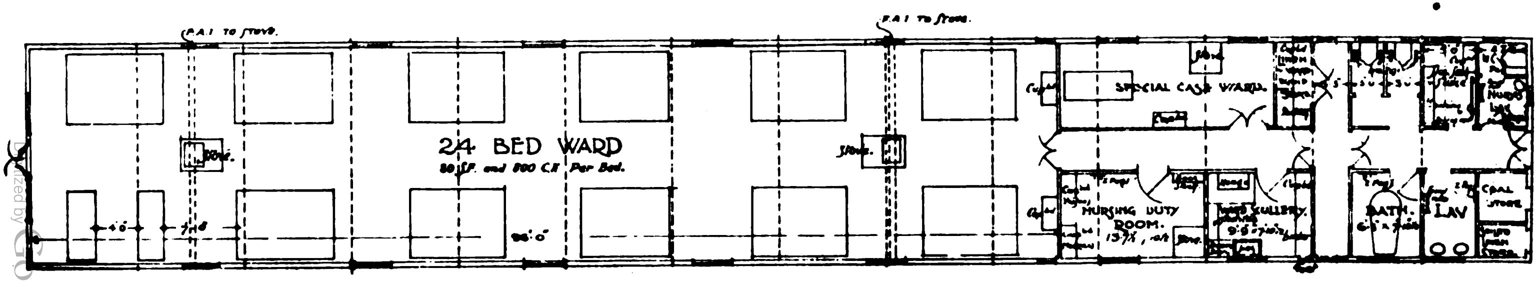
TC



Cupbd.
3·9"
21·7½"
ORDERLY MEDICAL OFFICERS ROOM
Stove
WARDROBE
Hat pegs
Shelves for Books 2 Tier
24·0"
Stove
Shelves for Books 2 Tier
BOARD ROOM.
15·10½"
Cupbd.
Hat pegs
✻F
✻F
WARDROBE
Hat Pegs
SISTERS ROOM
Shelving
MATRON'S OFFICE
12·0"
Cupbd.
Stove
6 Hat pegs
OFFICERS
W.C.
3·0"
4·3
LAV
Stove
Steriliser
11·10½"
Shelving. 2 Tiers.
Cupbd.
TABLE.
CLINICAL LABORATORY
24·0"
Sink
Glass
Sink
Sink
Shelf for Incubator
Vent.
Fume Cupboard
Glass
Shelving 2 Tier.
50
60
70 FEET

C & R.L TD. 749

FIG. 3. HUT HOSPITAL.



WARD BLOCK

sterilizing room, anæsthetic room, X-ray room and developing room. The kitchen of the hospital was rather more elaborate than the ordinary battalion type and had a dining room on each side of it. The ward blocks were designed to accommodate 24 ordinary cases and 1 special case. A nursing duty room, ward scullery, linen and ward equipment store, bath-room, w.c's., sluice room, lavatory, nurses' lavatory, coal store and soiled linen store were also provided in each block, which was of much the same construction as the ordinary barrack block, except that the walls were lined with fibrous plaster and the windows were specially designed in three sections, the middle section being provided with metal checks and made to open inwards. Large windows and a door, wide enough to allow a bed to pass, were placed in the end wall of the ward and windows were inserted in the gable. For each bed in the large ward 80 sq. ft. of floor space and 800 cub. ft. were allowed. In peace time the allowance per hospital bed is 120 sq. ft. of floor space and 1,200 cub. ft., and with a ward 25 ft. wide the wall space per bed is 8 ft., roughly 5 ft. between the beds. The hospital huts were, however, only 20 ft. wide, so that the 80 sq. ft. of floor space still permitted each bed to have 8 ft. of wall space although the actual cubic space was only 800 ft. In a hospital ward wall space is of prime importance and this having been assured in the hut design, the deficiency in cubic space was not so material and only came into play in the renewal of air without draughts, which it was hoped to effect by adequate perflation of air through open windows.

In the first design sent to commands in 1914, the lay out showed the administration block, operation block, kitchen block, and dining-rooms and hospital supply block in the centre, and the ward blocks in two columns on each side. The R.A.M.C. officers' quarters were in front of the hospital on the left and the nurses' quarters on the right; the R.A.M.C. orderlies' blocks, mortuary, pack store, and disinfecting blocks were placed at the back. There were no connecting corridors between the wards and blocks in the centre space. In a later lay-out issued in 1915, the administration block was shown in the centre of the hospital front, and from it a corridor passed down the centre of the ground to which the hospital wards and an operation block were attached by connecting passages. The main passage terminated at the dining rooms, kitchen block and supply blocks, which were placed at the back of the ground and approached by a separate road. The quarters for officers, sisters, and men, were arranged locally in the

position found most satisfactory. Usually, the officers' block was placed in front on the central drive to the hospital, the men's quarters behind the hospital, and the sisters' quarters to one side in a sheltered position. This lay-out was found satisfactory, and was generally followed in erecting hutted hospitals throughout the country. The general design of the operation block was subsequently modified, as the operation room was not large enough and the lighting was considered unsatisfactory (Fig. 4). A design finally approved by the Army Medical Advisory Board, containing two operation rooms, is shown in Fig. 5. As a type of the final evolution in hospital construction for war purposes may be mentioned the military hospital designed for the American Red Cross Society, after consultation with the medical branch of the War Office (Fig. 6).

The provision of hospital accommodation for cases of infectious disease arising amongst the troops had to be considered before the end of 1914. Cases of cerebro-spinal fever, measles, diphtheria, mumps and scarlet fever developed in various military centres, and where possible, existing civil isolation hospitals were utilized, the Government paying for each patient so treated. But the accommodation in most civil isolation hospitals was limited, as the buildings were only designed to receive the civil infectious cases arising in the districts which they served. In these circumstances the War Office invited the local sanitary authorities to erect at Government expense additional pavilions, of a type approved by the Local Government Board, on sites adjacent to existing isolation hospitals. Where the local sanitary authorities were not in a position to erect pavilions, the War Office did so, and removed the huts at the conclusion of peace. In some large camps, such as Ripon, a hutted hospital of 70 beds for the reception of infectious cases, was erected (Fig. 7). There were eight ward blocks, each containing a ward for eight beds, nursing duty room, ward scullery, ward equipment store, bath-room, sluice, lavatory, and w.c. Each bed in the ward had a floor space of 144 sq. ft. As the wards were only 20 ft. wide, the wall space was 14 ft., and in an emergency it was possible to put ten beds in each ward without unduly curtailing the wall space per bed suggested by the Local Government Board in their regulations for isolation hospitals. The hospital site also contained an observation block, in which there were a four-bedded and a two-bedded ward, separated by a nursing duty room, each ward having a sluice, bath-room and w.c.; a small administration block containing an office for the medical officer

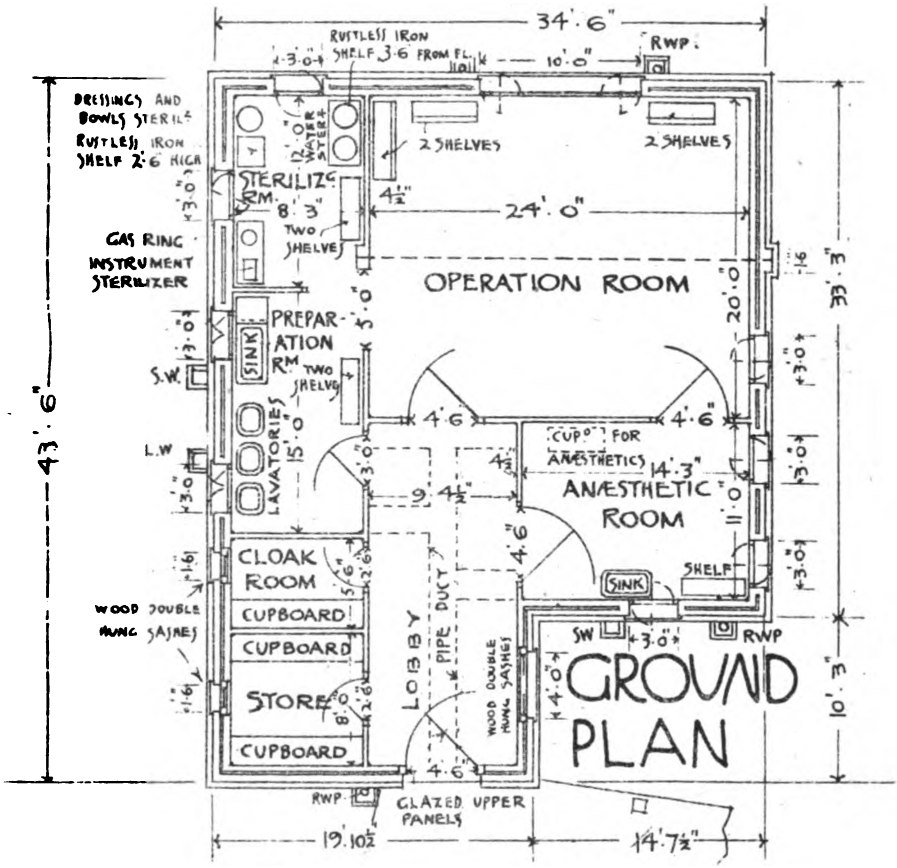


FIG. 4.

NEW DESIGN OF OPERATION BLOCK. NORTH WINDOW OF OPERATION ROOM CARRIED UP TO GIVE LIGHT TO THE BACK OF THE ROOM.

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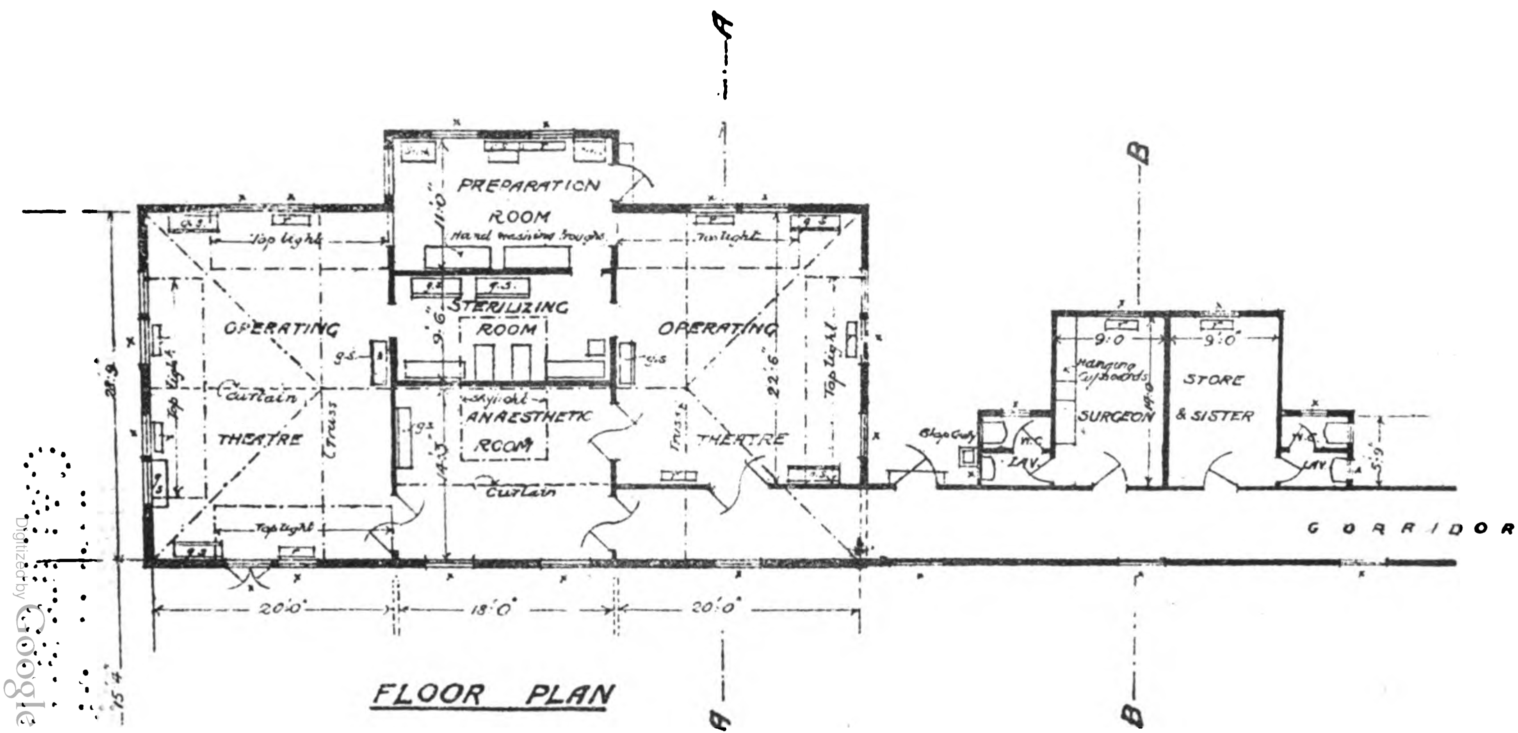

FLOOR PLAN

FIG. 5. HORTON (COUNTY OF LONDON) WAR HOSPITAL.
NEW OPERATING THEATRES.

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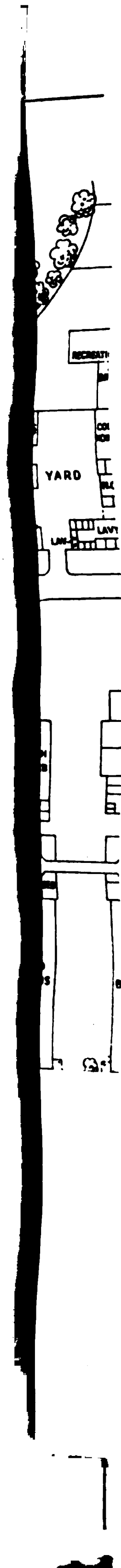
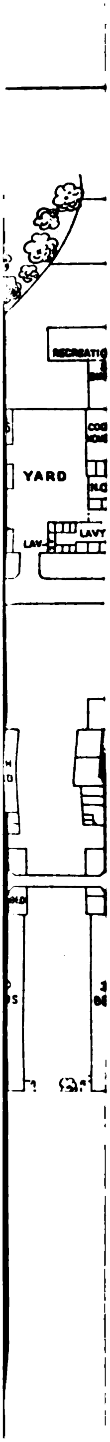

YARD


YARD
LAV

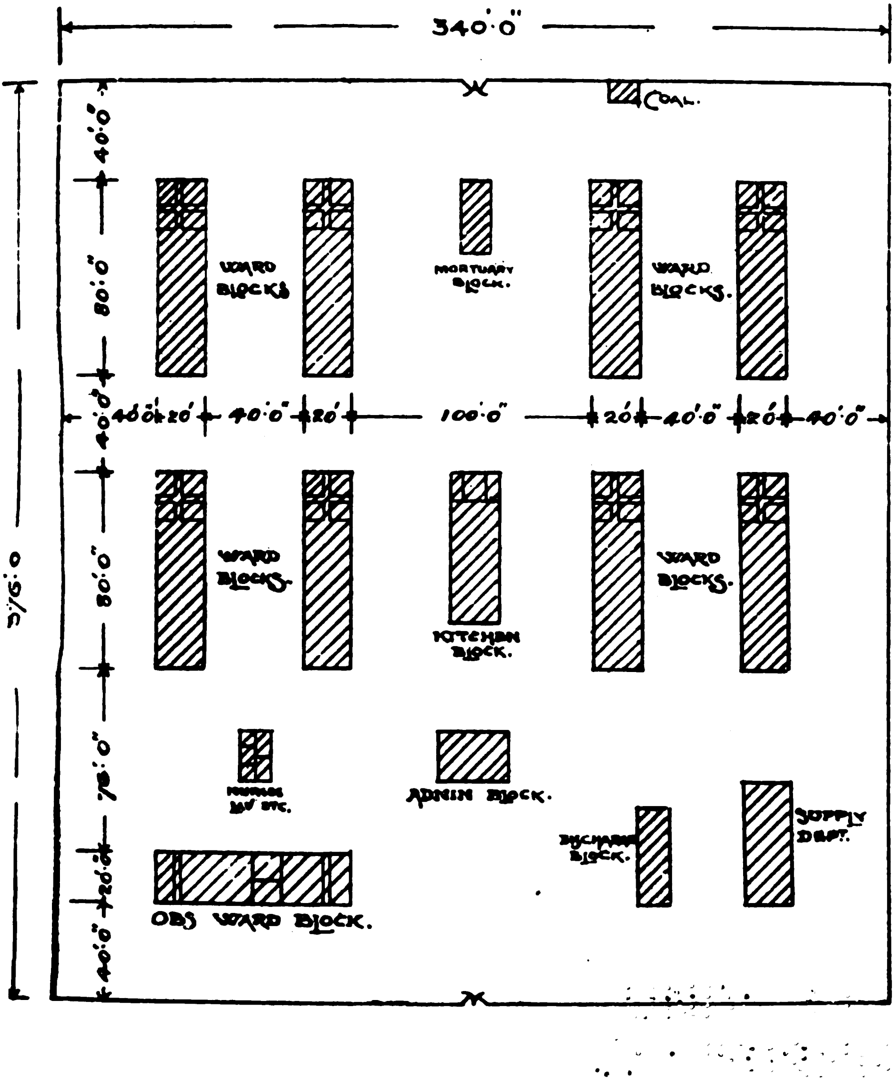


FIG. 7.– RIPON HUT HOSPITAL FOR 70 BEDS.
(INFECTIOUS CASES)
BLOCK PLAN.

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in charge; a small dispensary, and a duty room for the N.C.O. in charge; a discharge block of the usual type; a nurses' changing-room, containing a bath-room, lavatory, and w.c.; a kitchen of the usual type; and a hospital supply block. The hospital site, 340 ft. by 376 ft., was surrounded by an unclimbable fence, and between each of the wards and between the wards and the fence there was a space of 40 ft.

In 1915, the floor space per bed in hutted hospitals was reduced from 80 sq. ft. to 60 sq. ft., that is to say, to the allowance in barracks previous to the war. This reduction was viewed with considerable misgiving by the medical authorities, as in the ordinary ward 20 ft. wide it meant a wall space of only 6 ft. The space between beds was thus reduced to 3 ft., giving barely sufficient room for the ordinary bedside table. Such wards were overcrowded from a sanitary point of view, but for financial reasons, and owing to the steadily growing demand for hospital beds, it was felt that a trial should be made. Owing, however, to the extreme and anxious care taken by the medical and nursing staff, no untoward results occurred until the outbreak of influenza, when it was found necessary to remove some of the patients and accommodate them in tents. There was no doubt, however, that 60 sq. ft. per bed was too small an allowance in a hospital; it caused a great strain on the medical staff, and could only be justified by the exigencies of war.

The provision of beds for the sick and wounded was greatly helped by the establishment of a very large number of small hospitals, nursed by voluntary aid detachments, and other voluntary workers. These hospitals, mainly in large mansions and better class houses, were affiliated to central hospitals, from which they received convalescent and other cases not in immediate need of active surgical treatment. In some of the larger of these auxiliary hospitals operation theatres were provided.

A feature of the war was the creation of special hospitals for shell shock and mental cases, for orthopædic cases, jaw cases, limbless men, and of farm colonies for neurasthenics, and the development of convalescent hospitals, in which men were again made fit for work overseas by means of special exercises and graduated games. Special hospitals were also set apart as clearing houses for cases of dysentery and typhoid fever, and for malaria. Some of these special hospitals were in hotels, as at Barton-on-Sea, where hotel accommodation was extended by the use of huts The special hospital for

clearing cases of dysentery and typhoid fever at Addington Park was established in the Bishop's palace, and large huts holding 50 men were also erected. Others were in asylum and Poor Law buildings. The convalescent hospital at Eastbourne was entirely hutted. Others were under canvas or partly hutted.

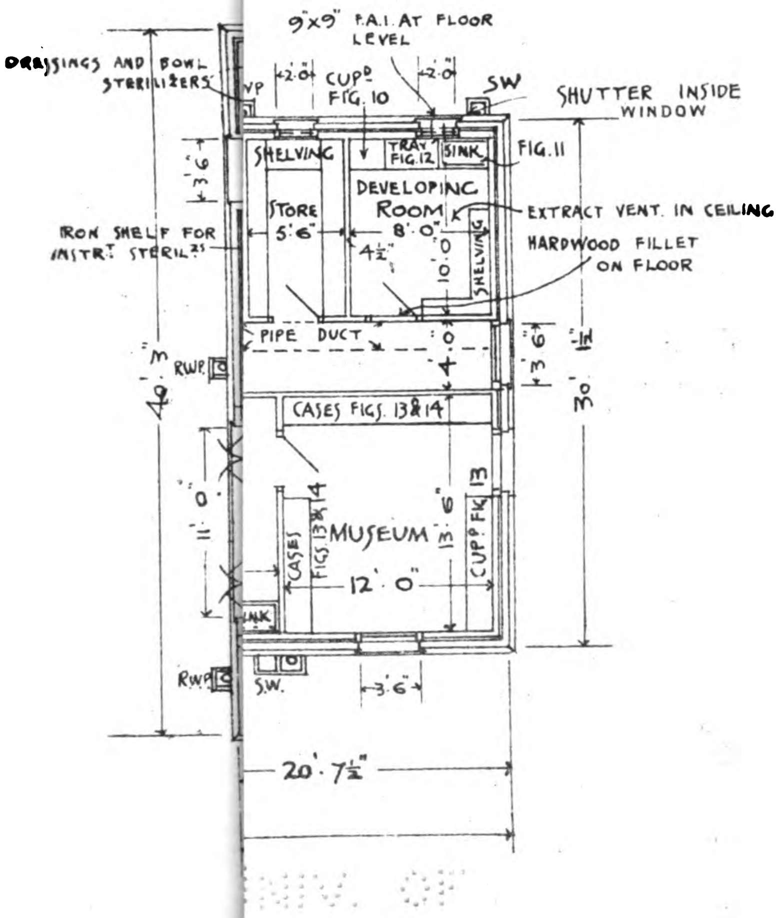
There were many new items of construction in the orthopædic hospitals, and the designs for the orthopædic centre erected in 1918 at Grangethorpe, Manchester, will serve to illustrate the final phases of construction for this special purpose.

The hospital was erected in the grounds of Grangethorpe House. All the buildings excepting the gymnasium and workshops were connected by covered corridors. The wards were 128 ft. long and 22 ft. wide, and contained 42 beds. About the centre of the ward on the east side was placed the lavatory block containing two baths, a sluice-room, three lavatory basins, and two w.c.'s. On the west side at the end of the ward was placed a covered verandah, access to which was gained by double doors in the wall of the ward. At the north end of the ward there were a duty-room, scullery and larder on one side of the passage, and a special ward and linen-room on the other side. The windows in the ward were carried up to the ceiling and divided into four sections, of which the highest and lowest were made to open inwards.

The main operation block shown in Fig. 8 was a new design, and contained a plaster room, casting room, and museum, in addition to the usual items of an operation block. Special lighting of the operation room was obtained by carrying up the north window to such a height that even in the winter months the back of the room was well lighted. The operation room was 24 ft. wide and 18 ft. deep, and had plenty of room for two tables.

The small operation block was of standard type, the lighting of the operation room being, however, similar to that of the main block.

The massage and hydrotherapeutic block was centrally placed in relation to the wards and was an L-shaped building connected by a covered way with the main corridor of the hospital. In the short leg of the building, running parallel to the main corridor, were placed the hydrotherapeutic room, 30 ft. by 22 ft., well lighted by windows at both sides and at the east end, and a store and room for an attendant. The long leg of



CENTRE

Malby & Sons. Lith.

the block was mainly occupied by the massage room, which was 80 ft. long and 22 ft. wide ; it was well lighted by windows at each side and at the south end. Next to the massage room were a large waiting room, and a small retiring room opening on to a passage connecting the massage and hydrotherapeutic departments.

The gymnasium was 60 ft. long and 30 ft. wide, and was well lighted by windows at the sides and both ends. It had ridge ventilators, and the windows were carried to the ceiling, the upper half being made to open outwards.

The workshops blocks were three in number. No. 1 contained the manager's office, general office, class-room, room for electrician, and a room for tailors and upholsterers ; this block was 73 ft. long and 18 ft. wide. No. 2 block contained the painters' shop, a room 10 ft. by 18 ft., and the carpenters' shop, a larger room 40 ft. by 18 ft., fitted with four benches. No. 3 block contained a shoemakers' shop, 20 ft. by 18 ft., with six benches ; the engineers' and splint makers' shop, which was 40 ft. long ; the acetylene and welding shop, 10 ft. by 18 ft. ; and the smiths' shop, 10 ft. by 18 ft., fitted with a portable forge.

IN FRANCE AND BELGIUM.

In the autumn of 1914 the field force in France was mainly housed in billets, empty buildings, tents, and bivouacs. On the lines of communication the accommodation was similar, except that bivouacs were not required. After the battle of the Aisne and the commencement of trench warfare, the lines of communication and the trench lines became more or less stable, and attention could then be given to the problem of housing the troops and sick and wounded during the winter months.

In November 1914 hospitals on the lines of communication were mainly concentrated at Havre, Rouen, and Boulogne.

The general hospitals in Havre were in buildings, but a stationary hospital and a convalescent camp were under canvas. At Rouen, too, a number of general and stationary hospitals were in tented camps. At Boulogne they were chiefly in hotel buildings and camps.

The regulation type of operating tent was not found suitable for the performance of serious operations, and the hospital marquees were too small to make efficient wards. Attempts were accordingly made to join up two or more tents to form one ward. Various methods were followed, the main difficulty

being to make the junctions of adjoining tents watertight. A method of joining tents was eventually suggested, and recommended for general adoption. The design of the tent was not altered in any way. In the case of two small hospital marquees joined so as to form a ward with a central passage of 5 ft. and beds on either side, the bases of the upright poles of each marquee were put 20 ft. apart and the tents pitched in the ordinary way, except that the ropes of the adjoining sides were passed round the vases of the poles of the adjoining tent, and so the outer roof covers were lifted up. A piece of Willesden or duck tent canvas, 22 ft. 6 in. by 2 ft. 4 in., was then hooked on the under side of the outer cover on each side, and so formed a gutter between the two tents. The outer covers thus joined were waterproof, and it was easy to raise the inner canvas and so form a long ward without a low roof at any point. The spare doorways were used to fill the gap between the inner roofs and the spare ends to fill the gaps at the sides.

Although tents joined in this manner were more satisfactory both for the patients and for administration than single marquees, it was found, especially in tented casualty clearing stations, that operating theatres and wards should have greater dimensions than the largest marquees, and just before the armistice the French " Bessonneau " hospital tent was recommended to replace joined marquees in casualty clearing stations.

At the request of the Army Sanitary Committee, two huts were erected in each of the tented hospitals at Rouen, one hut providing accommodation for the operation room and adjuncts, and the other for the reception of cases recently operated upon.

Later on huts were erected for several of the hospitals, and the lay-out followed generally the plan designed by the Director of Fortifications and Works in 1914. There were no corridors.

From the medical, surgical, and nursing points of view hotels and casinos at Boulogne and Wimereux were not ideal; in order to convert the rooms into ordinary medical and surgical wards considerable structural alterations would have been required, and while this expense was warranted at home, where the necessary labour and material could easily be found and it was known that the buildings would be occupied for a considerable time, in France the military situation in the early days of the war was so uncertain as to militate against any

attempt to erect on a large scale hospitals on the home plan. In 1915, however, the position had stabilized, and as large reinforcements were likely to arrive it was decided to make large hospital centres in various places. Etaples was selected as a centre for 5,000 beds, and in the interests of administration it was considered desirable to group the beds in units of 1,000. At a meeting held at Boulogne in January 1915, between the Army Sanitary Committee, the Director of Works, and the Director of Medical Services, Lines of Communication, it was agreed that the following accessories should be provided in huts: (1) operation room, with X-ray room, sterilizing room, and preparation room, and a recuperation ward, to accommodate patients after operation, in one block (two blocks were to be provided for each unit of 1,000 beds; (2) two 25-bed wards for serious cases, connected by a covered corridor with the operation block ; (3) a reception block, consisting of an undressing room, where new arrivals left their dirty clothes in racks, a bath-room, with hot and cold water, and six baths installed in cubicles, and a waiting room, where the patients received clean hospital clothing ; (4) cookhouses, ablution rooms, latrines for the hospital, and similar accessories for the staff ; (5) bed-pan cleaning place with water laid on in central situations in the proportion of one to every ten tents ; (5) a disinfecting hut, where dirty clothes could be dealt with.

It was anticipated that most of the patients would be housed in hospital marquees, but, as these were not then available, lined portable huts of 15 ft. span were erected. The male staff of the hospital was housed in tents, and the female staff in shelter huts of the Aylwin pattern. A convalescent camp of 1,500 beds was erected close to the hospital site and also an isolation hospital of 250 beds. The Liverpool Merchants' Hospital and the St. John Ambulance Hospital were also erected on the Etaples site at a later date.

At Le Tréport, in 1915, one hospital was in a hotel building, and two others in tents, with a hutted operation block between them, which was in the centre of an open corridor forming an octagon around it, and a recovery ward radiating at right angles from each side of the octagon.

A large hospital centre was also formed at Trouville. The hospitals were organized on a basis of 2,500 beds each in Nissen hospital huts, with one operation block and one set of administration huts. There were also convalescent depôts on the basis of 5,000 for each depôt in ordinary Nissen huts.

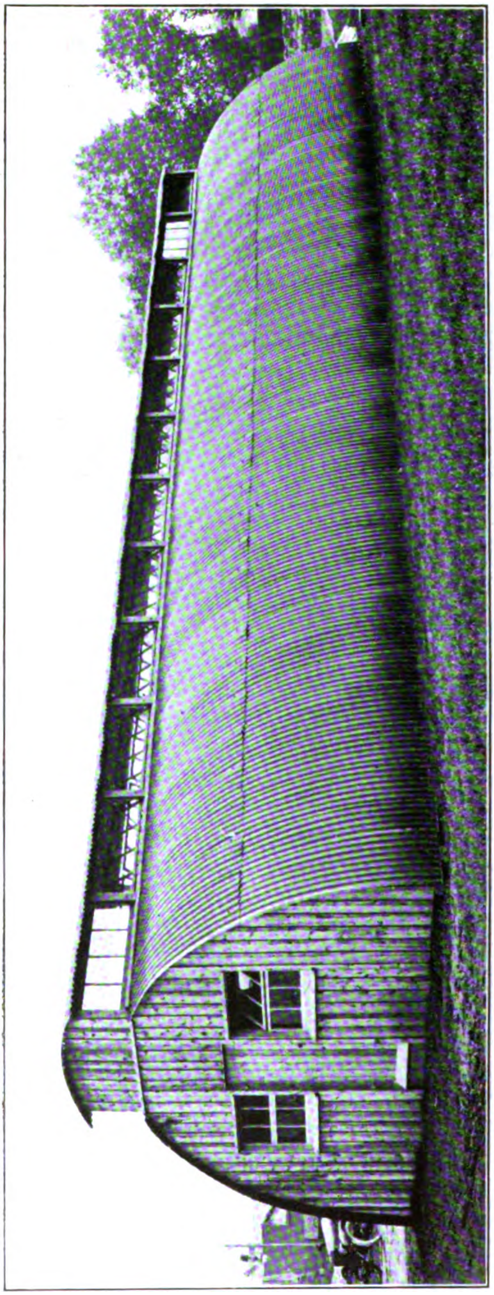


Fig. 9.—Nissen bow type hospital hut (outside view).

The Nissen hospital hut (Figs. 9 and 10) was bow-shaped and constructed of corrugated iron sheeting, lined with match-boarding. The inside measurements are 60 ft. by 42 ft. by 19 ft. 10 in., and the total floor area is 1,193·2 sq. ft. The hut was erected on bearers and unless the ground was flat it was

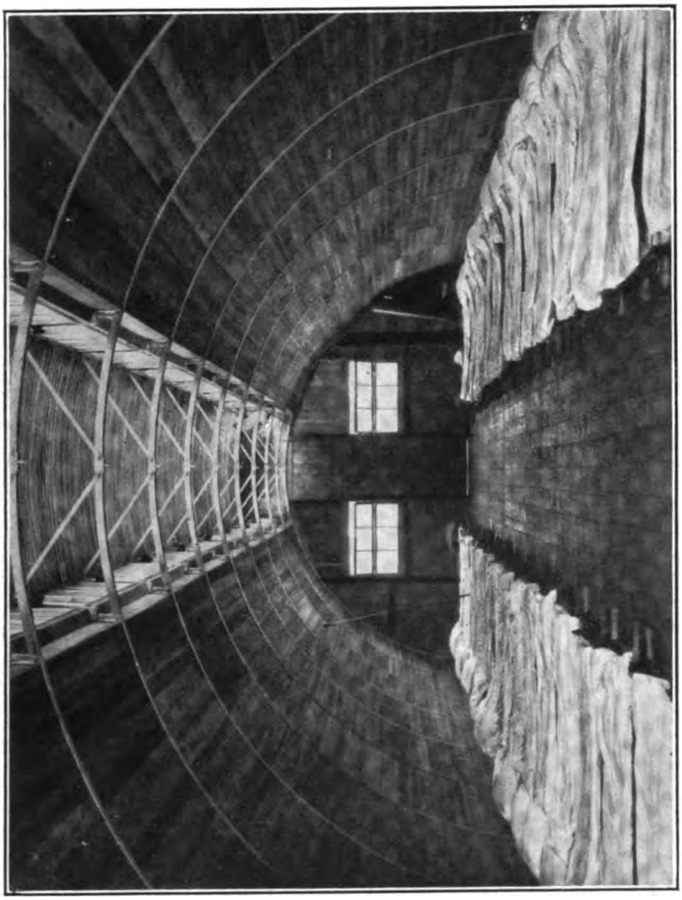


Fig. 10.—Nissen hospital hut (inside view).

found quicker to level up by inserting packing of wood or brick under the bearers rather than to level the ground. All that was necessary in this respect was to fill in any hollows which might allow water to collect under the hut. Floor joists were laid on the bearers and the floor panels then laid on the joists. The curved corrugated iron sheets which formed the sides overlapped

two corrugations laterally and the outer sheets the end panels with three corrugations. On the top of the hut there were 24 lantern-light windows, 12 on each side. Each window had four panels, glazed with oiled fabric fixed by wooden fillets ; the sash was hinged at the bottom with two butt hinges, arranged to open inwards, and supplied with window stops to allow the window to open 45°. The end panels of the hut each contained two large windows 3 ft. 10 in. by 2 ft. 8 in., having eight panes of oiled silk set in wood frames ; the upper sash, containing four panes, had butt hinges, arranged to open inwards, and was supplied with webbing at both sides attached to the frame and sash, to allow the window to open 45°. In each of the end panels there was also a door 3 ft. by 6 ft. 6 in., made of tongued and grooved wood. In a later type the hut was lined with corrugated iron instead of match-boarding.

The Nissen hospital hut had been introduced for use in casualty clearing stations at the front and was intended to accommodate 40 patients, but in accordance with the decision that every patient in a permanent hospital must have 6 ft. of wall space the Nissen hospital hut on the lines of communication provided accommodation for only 20 patients. At Trouville, 25 patients per hut were allowed, as the majority of the cases treated there were not seriously ill.

The ordinary Nissen hut used for troops was also bow-shaped and constructed of corrugated iron sheets lined with match-boarding (Fig. 11). In a later type, corrugated iron lining was substituted for match-board lining. The size of the hut inside was 26 ft. 10 in. by 15 ft. 8 in., and it had a floor space of 420 sq. ft. The floor was made of 1-in. boarding, tongued and grooved. There were four windows, two in each end. Each window had four panes of oiled linen measuring 1 ft. 5 in. by 1 ft. 4 in. ; the two upper panes were set in a sash and opened inwards. In the entrance end there was a door 2 ft. 6 in. by 6 ft. 6 in. made of ¾-in. tongued and grooved boarding, placed in the centre between the two windows ; the closed end had also two windows and a hole 6 in. square cut in the centre panel for a stove pipe, with an iron plate affixed, and a ventilation hole 20 in. by 5 in., which could be closed by means of two slides.

The ordinary Nissen hut accommodated 14 men, which gave rather less than 4 ft. of wall space to each man.

One such hut was allowed for four nursing sisters, the interior being arranged to contain four cubicles, with a central passage between them.

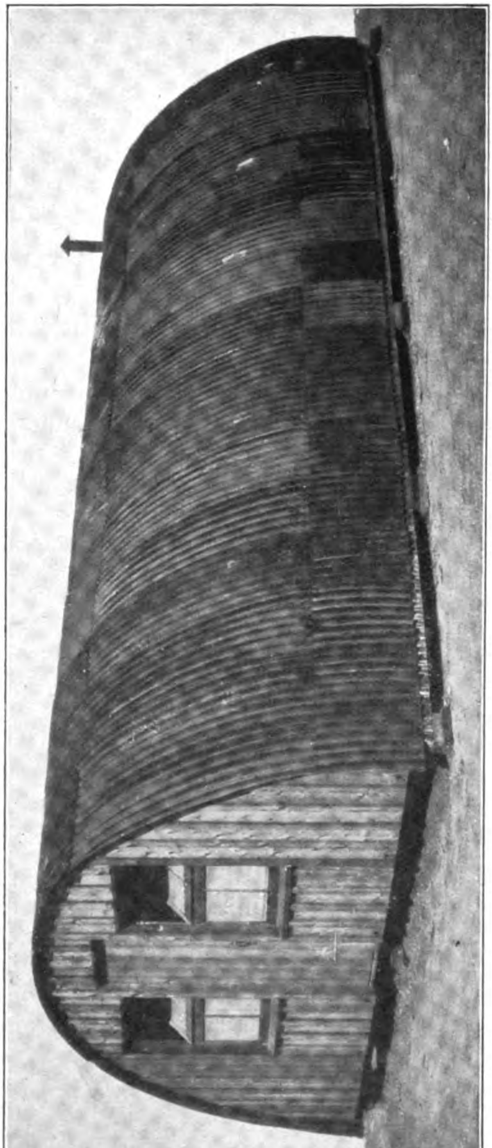


Fig. 11.—Nissen hut for troops.

At Trouville, the Nissen hospital huts were grouped, but experience showed that from the nursing point of view the best arrangement was to have the huts in pairs, with a nursing

duty-room and a ward scullery between two huts as shown in Fig. 12. This arrangement was first adopted at No. 10 Canadian Stationary Hospital, Calais, and was found most convenient.

Early in 1917, it was decided that all hospital marquees should be replaced by huts of the French Adrian pattern. The hut was 110 ft. long and 21 ft. wide between the uprights, but 27 ft. wide at the floor. The walls were lined up to the bottom sill of the windows; the floor was of wood and laid in sections. There was a window in every second section and double doors 4 ft. wide at each end. The roof was of ruberoid or similar material. Two small rooms about 10 ft. by 8 ft. 6 in. were formed by partitions at one end

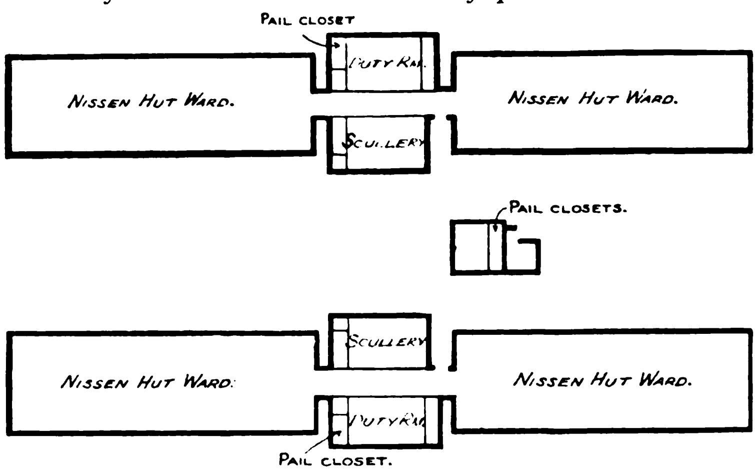
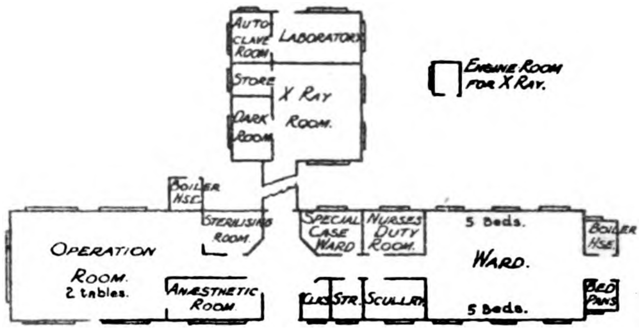


Fig. 12.—Nissen hospital huts at Trouville.

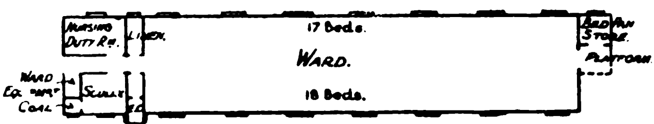
of each hut. In one room, the nurses' duty-room, a cupboard and shelves were fitted, and in the other, the scullery, a sink with necessary drainage was arranged where possible. The ward was heated by stoves and accommodated about 40 men. Each hut occupied the same space as three hospital marquees connected lengthwise, and when erected with a minimum space of 15 ft. between the huts, it was found that the huts exactly took the place of the marquees as then arranged. The A.D.M.S. (Sanitation) suggested that the sloping sides of the hut should be waterproofed with ruberoid or similar material, as it was found that the drippings from the roof leaked through the sloping sides and made the interior of the hut damp.

As a result of the experience gained at Etaples, it was recommended that an admission and discharge hut should

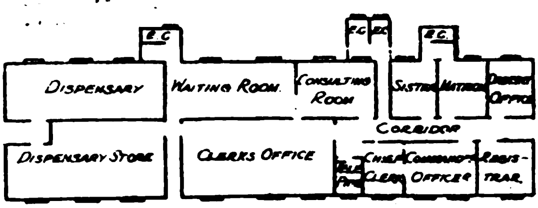
PLAN OF OPERATION BLOCK, WARD HUT, AND ADMINISTRATION BLOCK, FOR GENERAL HOSPITAL OF 1040 BEDS IN FRANCE.



(a) OPERATION &c. BLOCK.



(b) WARD.



(c) ADMINISTRATION.

SCALE.
10 5 0 10 metres

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FIG. 13.

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be provided in each general hospital for the reception of patients on arrival, and also for their accommodation prior to evacuation, the hut to have a floor space of at least 2,000 sq. ft. and to be properly heated. In most general hospitals the need of such a hut had been felt and provided by misappropriation; it enabled ambulance cars to be unloaded and loaded rapidly and before transference to the wards patients could be examined at leisure and bathed in a bathing room containing shower and a few long baths attached to the hut. Consequently, an admission block, containing a reception room and a bathing department was approved for all large hospitals in France in September 1917. A central dressing room, equipped with sterilizers, was also found useful; here patients able to walk from the wards could be dressed with a minimum expenditure of time and a smaller staff was required than when the dressings were done in the wards.

In November 1917 type plans were issued by the Director of Works in France to be used in connection with the scales of accommodation approved in October 1917 for the lines of communication. For a general hospital of 1,040 beds the following accommodation was provided :—

(1) A combined operation, X-ray, laboratory and resting ward block. The design is shown in Fig. 13 (a). In connection with the operation room on the left of a central hall, there were a sterilizing room and an anæsthetic room. On the right of the hall, associated with a ward containing ten beds, were a special case ward, nurses' duty room and scullery. The X-ray room, dark room, store, laboratory and autoclave room were in one building connected by a ventilated corridor with the hall of the operation block.

(2) General surgical dressing hut. This was a building 5 metres by 12 metres, and consisted of a waiting room and a dressing room, fitted with a sink, dressing table, cupboard and stove.

(3) Administration block. The design is shown in Fig. 13 (c). It contained all the usual offices as well as a dispensary and dispensary store.

(4) Reception room. This was a large room, 30 metres by 8·5 metres, warmed by stoves, and well lighted by windows and skylights.

(5) Ward huts (Fig. 13 (b)). Each hut contained 35 beds, and had a nursing duty room and scullery at one end with a compartment outside the ward for a commode and bed-pans. The cubic space per bed was 500 ft. and the floor space 50 sq. ft.

A double ward block had a single nursing duty room and scullery placed between two wards.

(6) A supply department, pack store, cookhouse and a dining room for 25 per cent. of the hospital accommodation.

(7) Bed-pan cleaning shed, disinfector block, latrines, ablution room, baths, incinerator sheds and a mortuary.

(8) Accommodation for the staff. This was planned much on the lines of the hospitals at home.

Casualty Clearing Stations.

The accommodation for casualty clearing stations varied very considerably according to localities and to the individual views of Ds.M.S. of armies. In the earlier stages of the war they were almost invariably in buildings, generally schools or other institutions, expanded by tents, but as the enemy's artillery fire began to make such buildings untenable, special sites were selected for grouping casualty clearing stations under canvas or in huts.

In September 1917, the functions of the casualty clearing station were determined as follows: (1) to provide hospital accommodation, nursing and treatment for patients unfit for further transport — the hospital section; (2) to provide temporary surgical treatment, shelter and food for patients pending transfer to the base—the evacuation section; (3) to retain slighter cases of sickness and wounds pending return to duty or transfer to a rest station—the convalescent section. Accordingly, a new scale of equipment was drawn up representing the maximum amount of tentage considered necessary to equip fully a casualty clearing station when accommodation in buildings or huts was not available. In this scale, 81 small hospital marquees for patients and dispensary, 35 single-lined circular tents for the staff, 15 double-lined circular tents for the nursing staff, and one store tent were provided.

Where accommodation for casualty clearing stations could not be found in existing buildings, huts each 60 ft. by 20 ft. were provided for an officers' ward; for men's wards, for 112 serious cases (four huts); for an operating room; a receiving and dressing room; patients' dining room; patients' recreation room; and for administration and stores. The remainder of the accommodation required was to be provided in marquees with boarded floors. The medical officers were to be housed in Armstrong hut-tents, the nursing sisters in small

Nissen huts or in Armstrong hut-tents, and the men as for troops in the vicinity. Cooking shelters, latrine shelters, an ablution room block, a bath-house with shower-baths, an incinerator shed and a portable disinfector shed were also to be provided. The administration block, the operating and receiving rooms, officers' wards and men's wards for serious cases were to be lighted by electricity.

In September 1918, it was generally agreed that the double general service marquee was not the most suitable pattern of tent for casualty clearing stations. Trials were then carried out at Nos. 1 and 23 Casualty Clearing Stations in the First Army with the French Bessonneau tent ; it was found in every way a great improvement on the British marquee, being commodious, light, portable, easily pitched and struck. It was 18 metres long, 6 metres wide, and the height to the top of the walls was 2·25 metres and to the ridge 3·5 metres. It had a framework of wood, an external covering of tentage material, an internal lining of cotton and 18 glass windows. Its total weight was 826 kilos. The D.G.M.S. strongly recommended that the Bessonneau tent should be adopted for the wards and operating theatres of casualty clearing stations, and that the regulation marquees should be used for dispensary, stores and other accessories.

A meeting of the officers commanding casualty clearing stations was held at St. Pol on 16th September 1918, when, in addition to 57 tents of other types and 20 general service marquees, 24 tents of the Bessonneau type (reception 2, dressing 1, theatre 1, pre-operation 1, resuscitation 1, patients 18, including 2 for officers), were recommended for a casualty clearing station of 400 beds.

It was also recommended that the Bessonneau tent for an operating theatre should have two additional bays, making it 80 ft. long, and that 5 additional Bessonneau tents should be provided to add 100 more beds to the accommodation.

No further action, however, was taken to provide these tents owing to the cessation of hostilities.

Accommodation for Troops.

In September 1917, the Quartermaster-General, G.H.Q., France, issued instructions for the accommodation of the troops during the winter 1917-18. Troops in the front line were to be housed in underground shelters, which were to be lighted and heated, under arrangements made by army commanders. Troops in rear of the front line were to be accommodated in

billets, but if these were bad, or insanitary, or not available, the troops were to be placed in huts, whenever possible within the sheltered area. In all cases drying rooms, including

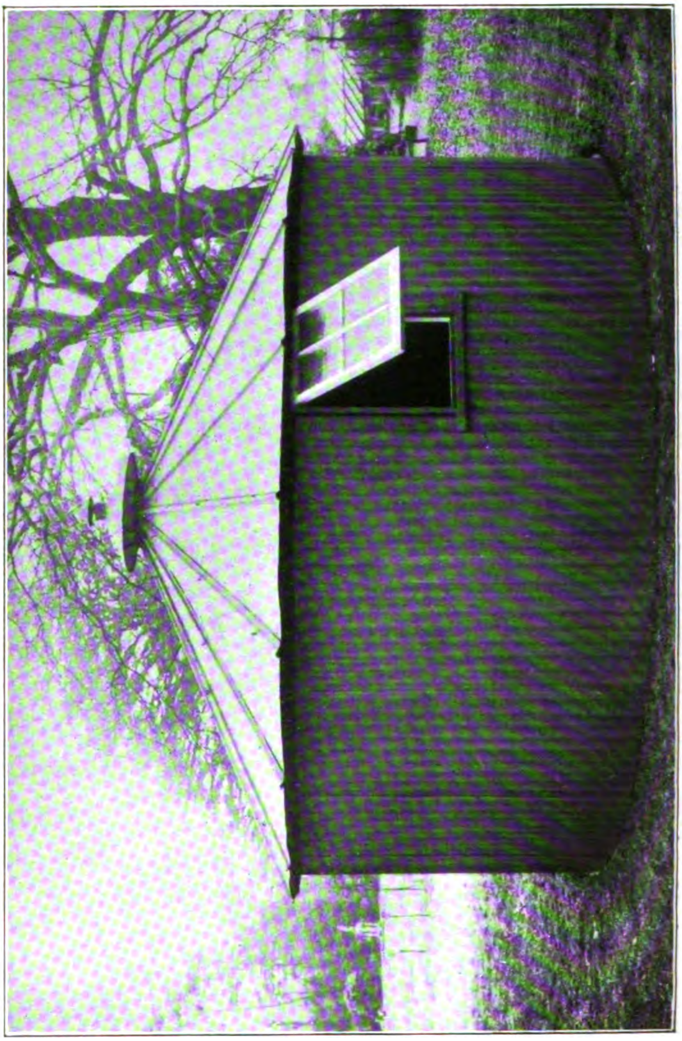

Fig. 14.—Nissen steel tent.

provision for changing and drying boots near the trenches, cooking shelters, ablution sheds, latrines and a destructor were to be provided as hutted accessories.

In the rear zone if material was available, officers' messes, sergeants' messes, bath-houses, recreation room, orderly room, and Q.M. office and stores were also to be in huts.

In June 1918 the Nissen steel tent (Fig. 14) was brought to France for use in the forward areas. The tent is a circular structure having vertical walls made of 20 sheets of corrugated iron, the junctions being made by metal grooves in which the sheets slide. The roof is conical and is composed of sections of sheet iron fitted together on rafters. The roof is also furnished with an inner lining of sheet iron. A ventilator is provided at the apex. The door consists of a single sheet of corrugated iron, 2 ft. 3½ in. wide, and two oiled linen windows which can be opened are let into corrugated iron panels on opposite sides of the tent. The floor is of wood. The diameter of the tent is 14 ft. 6½ in., about 2 ft. more than an ordinary bell tent. There is practically 44 ft. of available wall space, omitting the space occupied by the door. Eleven men could thus be accommodated in the tent giving each 4 ft. of wall space. Kits can be hung from the eaves inside the tent, thus avoiding encumberment of the floor. A small stove can be placed in the centre of the hut and a flue pipe carried up through the apex of the roof. The Nissen tent was adopted for use in forward areas as it had the advantages of being cheap, easily and rapidly manufactured, easily transported and erected. Three Nissen steel tents accommodated 33 men, weighed 1,857 lb., and cost £63, whereas one Nissen hut, which held only 14 men, weighed 5,103 lb. and cost £76.

In addition to the huts described above several other types of huts were used on the lines of communication in France, some being of local or improvised pattern.

In view of the increase of bombing by enemy aircraft in August 1918, it was considered necessary to standardize the accommodation for all armies. Army areas were then divided into four zones :—

(*a*) The forward zone, in which the troops lived in dugouts.

(*b*) The secondary zone, in which the troops lived in dugouts or shelters.

(*c*) The reserve zone in which the troops lived in any available billets supplemented by huts erected in such a way as to conceal them as far as possible from enemy aircraft.

(*d*) The back zone, in which the troops lived in billets, or in hutted or tented camps.

In the forward zone no dugouts were provided in the front line, only splinter-proofs, and these were for about three or

four men, about one per section of the garrison. In the support line, platoon dugouts, if tunnelled, were chambers about 18 ft. long and 9 ft. wide; bunks were in three tiers, each two feet wide, and arranged at right angles to the sides. If timbered with wood frames the chambers were about 5 ft. 6 in. wide, the bunks were in two tiers on each side and parallel to the sides, and there was a passage way in the middle. If dugouts were not tunnelled at least two per platoon were provided to minimize casualties in case of penetration.

In the reserve line the same arrangements were made. At battalion headquarters dugouts were constructed for a mess room about 15 ft. by 9 ft., a battalion office about the same size, and for other ranks one similar to a platoon dugout. There were also dugouts for about five officers.

The class of accommodation and degree of protection afforded for regimental aid posts varied very greatly. The requirements were a dressing room 12 ft. by 9 ft., space for accommodating 8 to 12 stretcher cases awaiting evacuation, facilities for cooking and a supply of hot water, quarters for the medical officer, his N.C.O. and one or two bearers, and in addition accommodation for a field ambulance relay post, *i.e.*, four R.A.M.C. bearers who, as a rule, were attached to the aid post. The degree of protection afforded in these medical posts varied from just sufficient for protection from splinters and small fragments of shell to the maximum protection that would withstand a direct hit from shells of howitzers or other form of heavy artillery.

A splinter-proof aid post consisted of galvanized iron roof and walls protected by one layer of sandbags. The roof did not project above the ground level. Instead of flat sheets of corrugated iron, a device made of sheet iron known as an "elephant shelter" was often employed (Fig. 15). The section or arc of these shelters was 9 ft. 6 in. wide at the base, and 6 ft. 2½ in. in height. Each sheet 2 ft. 9 in. wide, was made to overlap the next and any number could be used. A shelter 20 ft. long was most convenient, taking a rack of six stretchers on each side and this could be connected by a passage to another shelter about 12 ft. 6 in. long, used as a dressing room.

A shell-proof aid post required 20 ft. of cover overhead and where the subsoil was chalk the dugouts were dry and fairly warm (Fig. 16). In the Hulluch tunnel, which was lit by electricity, an aid post was cut out of the solid chalk and consisted of a dressing room about 12 ft. by 9 ft., accommodation for 12 stretcher cases in tiers, a dugout for the medical officer and one for the R.A.M.C. relay post within 20 yds. of the dressing room.

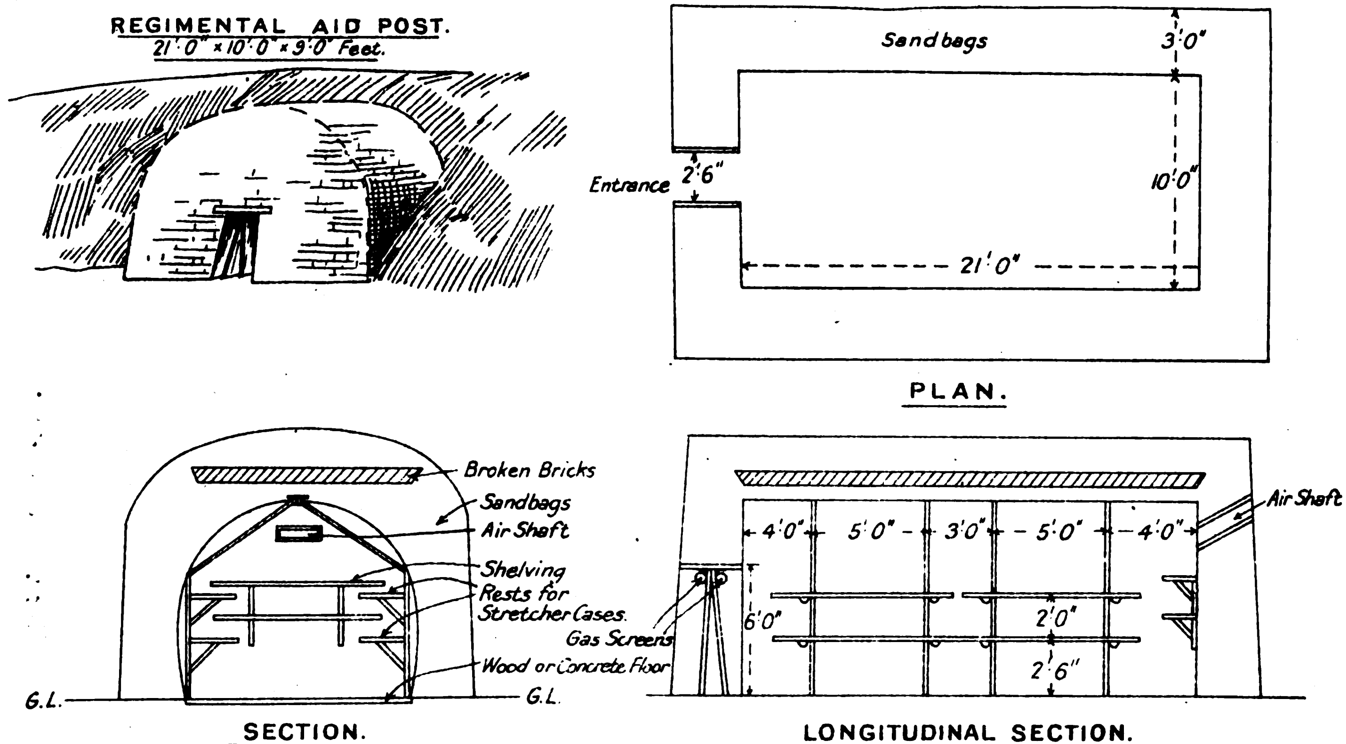

FIG. 15.

REGIMENTAL AID POST. "ELEPHANT SHELTER".

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A separate entrance and exit were invariably constructed in these deep dugouts. The entrance might either be long and with a gradual slope, or short with a slide for the stretcher, and steps for the bearers.

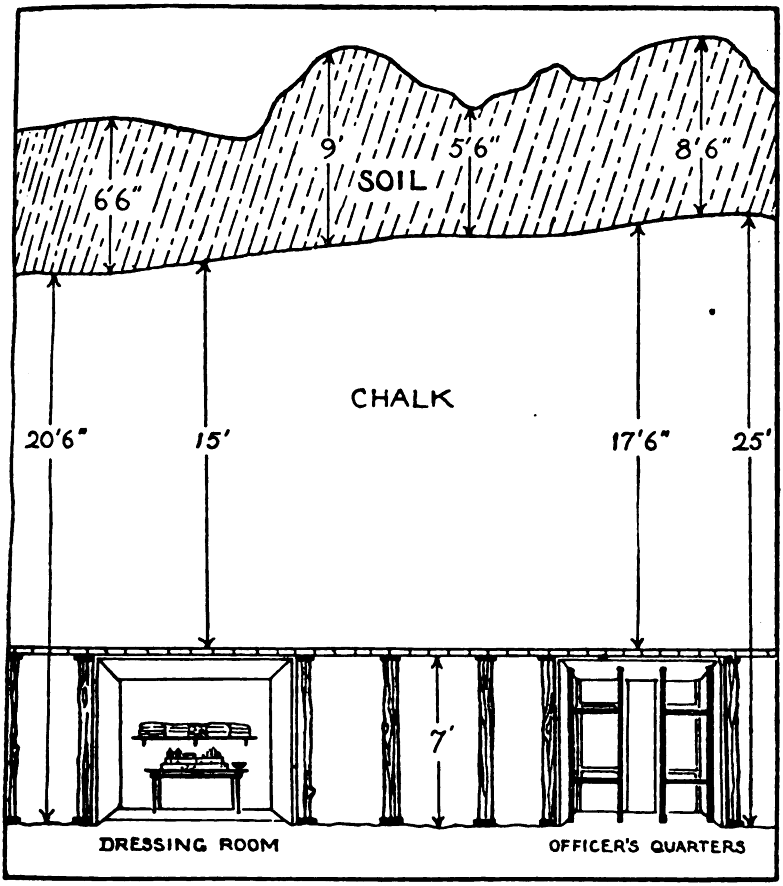

Fig. 16.—Shell-proof aid post.

In ruined houses and villages aid posts were formed in the cellars with the roofs supported by stout pieces of timber placed vertically and horizontally; the ground floor of the houses which formed the roof of the cellar would be covered with several layers of sandbags, sleepers, rails, and sometimes with fallen bricks and masonry.

Occasionally, there was more room than was actually required. For example, in the cellars of the Civil Hospital

of Lens, where a battalion headquarters and aid post were located, the medical officer had a spacious dressing room, 20 ft. by 15 ft. at least, accommodation for 20 or more stretcher cases, and plenty of spare room in small cellars, which communicated with the dressing room. The battalion headquarters was in an adjoining series of cellars.

In open warfare regimental aid posts were located in houses, outhouses, barns, abandoned army huts, cellars, in captured medical posts of the enemy, and sometimes in the open or in a sunken road.

Advanced dressing stations were formed in cellars or other protected spaces (Fig. 17). When "elephant shelters" were used, as was commonly the case in the later stages of the war, an advanced dressing station was usually formed of a 20-ft. shelter for lying cases, connected by a passage to another 12-ft. shelter as a dressing room. The arrangements for cooking and the supply of hot water were installed on either side of the passage connecting the two shelters.

The floors of the shelters were boarded and racks were constructed to hold the stretcher cases in tiers, and the whole shelter was protected with two layers of sandbags, with additional protection against bombing by means of walls of sandbags about 6 ft. high.

When cellars were utilized as advanced dressing stations additional protection was sometimes afforded by constructing a second roof to carry at least three layers of sandbags, with an air space of perhaps a couple of feet between it and the roof proper. This method was employed in the advanced dressing station at Vermelles, the work being carried out by working parties of R.A.M.C. bearers, under the supervision of Royal Engineers.

The advanced dressing station in the Cité St. Pierre, Lens, was an example of another type, suitable accommodation being provided by connecting together four adjoining cellars of artisans' dwellings. The roofs were supported by timber placed vertically and horizontally, passages were made that would admit of stretcher cases being carried through from one cellar to another and separate entrances and exits were constructed. The first cellar served as entrance and reception-room, the second as a dressing-room, the third was fitted with racks to accommodate 12 or more stretcher cases. From this cellar the exit led out on to a light railway, by means of which cases were evacuated at night. The fourth cellar provided accommodation for two medical officers and other personnel of the advanced dressing station.

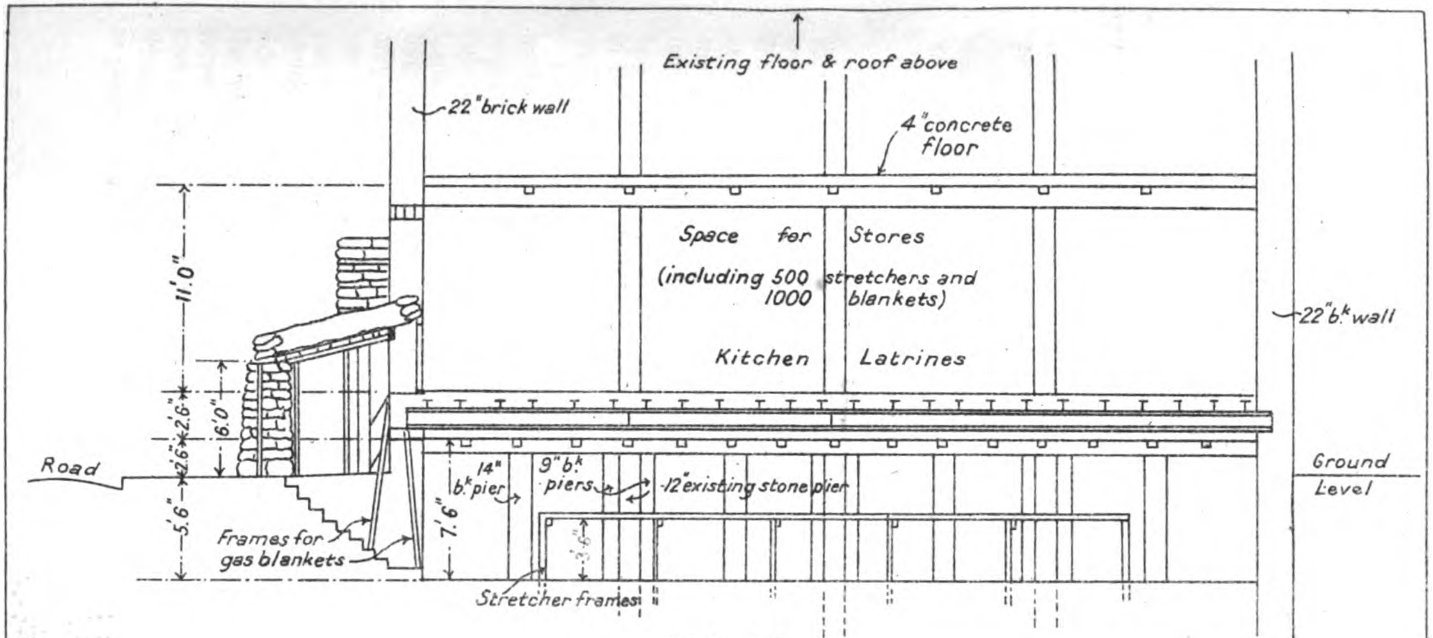

FIG. 17.

ADVANCED DRESSING STATION, RUE ST MICHEL, ARRAS.
TO HOLD 138 PATIENTS.

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Malby & Sons, Lith.

In the secondary zone a standard cast-iron bivouac shelter was erected. Corrugated iron sheets were used, 9 ft. long by 2 ft. 2 in. wide, with an overlay of one corrugation. In one type, the sheets rested on sandbags and were attached by plain double wire to wood pickets inserted between the bags; the shelter was 7 ft. wide and carried no weight on the top. In the second type, the shelter was 13 ft. wide, and formed by two sheets, joined in the centre and supported by wood pickets and angle iron at the ground level; this shelter was covered with one layer of sandbags.

In the reserve and back zones when laying out new hutment camps the huts were separated as much as possible, camps for companies or even platoons being considered preferable to battalion camps. Huts were surrounded by a splinter-proof earth wall, built to a height of 3 ft. above the inside floor level and revetted with the most durable material available.

IN MACEDONIA.

The hospitals were either hutted or under canvas. In the earlier period of the allied occupation of Salonika, tents only were provided, but in 1916 three hutted hospitals were constructed on a site at Kalamaria, on the east of the harbour, at the outskirts of the town. They were about 100 ft. above the level of the sea. The centre hospital was built of local materials, timber framing, weather boarded walls, match-boarding and tiled roofs. The other two hospitals were built of English and Egyptian pattern huts, having weather boarded walls and felt roofs.

The original asbestos and three-ply linings had been much broken up in shipment, and a large number of huts were consequently completed with linings of white canvas, sized and painted. In all three hospitals the N.C.Os. and men were in tents. The sisters were provided with huts, and the officers had living and mess huts in the centre hospital and mess huts only in the others. As soon as the huts were taken into use it was found that they were very hot and stuffy in the summer months, especially those with felt roofs. To obviate this, canvas screens were provided on the sunny side to shade the windows and two sections were cut out of the walls of each ward to afford additional ventilation and serve as emergency exits in case of fire. These openings were curtained with mosquito netting. The upper panes were also removed from the windows and mosquito gauze frames fixed in place. All these openings had to be closed in again for the

winter. Second roofs of corrugated iron were also placed on those of the sisters' huts which had felt roofs. In the summer of 1917, a limited number of reed mats was available. They were used for double roofing some of the felt-roofed wards. The matting was removed in winter and stored for use the following summer when the other wards were also provided with similar double roofs. About 200 huts were treated in this way, using an average of 100 mats per hut. In the spring of 1918, four additional sections were removed from 166 wards, and 140 wards were provided with verandahs with canvas roofs, some 4 ft., and others 8 ft. wide. This work was completed by midsummer, and other improvements and additions were also carried out as found necessary during the two and a half years these hospitals were in use. Additional officers' wards and five small wards for senior officers were added to one of the hospitals, thus providing accommodation for 68 officers. A ward for sick sisters was provided in 1916; it was augmented by several additional wards of local design during 1917, to provide for a total of 50 sick sisters with special wards for infectious cases. This was further extended in 1918 to provide hutted accommodation for a total of 100 sick sisters.

In 1917, the hospitals on the Kalamaria site, except the central hospital, were each provided with five shelters 70 ft. long by 18 ft. wide, made of old ground sheets and rush mats, each shelter accommodating 30 patients.

The hospitals were provided with electric light, the power being obtained from a central station.

At other places, as at the convalescent camp on the Kirechkoj plateau, huts were built of local stone and mud with corrugated iron roofs.

A convalescent depôt on the Hortiak plateau was provided with Nissen huts in place of tents at the end of 1918.

Red Cross kitchens were provided at all hospitals for use by V.A.D. cooks to provide special articles of diet which could not be provided in the main kitchens. The earlier kitchens were made with lathing of reeds fastened on timber framing, strengthened with hoop iron bands from forage bales and plastered with mud; roofs were of petrol boxes nailed together. Some of these stood very well but others did not survive the winter. Later kitchens were, therefore, made with half brick walls and timber framing with ordinary roofs.

In the summer of 1917, convalescent depôts were provided with open-air shower-baths screened where necessary. In

several cases the French pattern light portable shower-baths were used. For winter use five convalescent depôts at Salonika and one at Stavros were provided with bath-houses.

In the summer of 1917, as several of the hospitals and convalescent depôts were only expected to be in use for a few months, and suitable materials and labour to floor cook-houses, ablution sheds and latrines were not available, only metalled floors were provided in many cases.

In the beginning of 1918, a large number of bricks became available from the part of Salonika which had been burnt down in the previous August. It was decided to make use of these to provide more satisfactory floors in the hospital buildings. The work was carried out, the number of bricks used being approximately 230,000.

In September 1917, it was decided to provide at four hospitals special dysentery enclosures to contain 200 beds and smaller enclosures at three other hospitals. Later on an enclosure was provided at Stavros also. In general, these enclosures consisted of an area surrounded by a wire fence and subdivided into three separate enclosures. These were provided with separate latrines and sheds for washing and storing bed-pans, which were kept in fly-proof safes. A single cook-house about 28 ft. by 18 ft. was provided for the block and also a dugout for the sisters when the enclosure was any considerable distance from the main hospital. An ablution shed was also provided in some cases. Special incinerators were provided for the compounds.

Later on complete hospitals were set aside for dysentery patients.

Certain hospitals were kept open all winter and additional buildings such as bath-houses, laboratories, operating theatres and disinfector sheds were provided for their use. The remaining hospitals were closed, but as the fall in sickness was gradual it was not possible finally to close down these hospitals till December or later each year. In order to give the maximum of ventilation and keep down flies, cook-houses and ablution rooms were kept as open as possible during the summer, one or two sides being completely open and the others partially so. In autumn each year all these buildings had to be closed in and reopened in spring.

The question of rendering all huts, used for sleeping and eating, in hospitals mosquito-proof and fly-proof and of providing mosquito-proof huts for units in low-lying localities of the base area was raised in winter 1916. Owing to the cost involved it

was decided to confine this work to hospitals and sleeping huts already in existence and to the fly-proofing of dining huts.

Special mosquito-proof shelters were used in the front line. Mosquito netting was put across the doors of ordinary dugouts but this was not successful, constantly getting torn and also hindering ventilation.

In bell tents ordinary hospital mosquito nets were used. One net to every two men was the usual allowance, but was not very satisfactory and also was constantly torn.

At the base and elsewhere where large huts were used, one hospital pattern mosquito net was allowed to each bed, or one to two men when not given bedsteads.

In Bulgaria, Constantinople and the Caucasus, the men were housed for the most part in vacant barracks. Those in Turkey were very foul and required a great deal of cleaning. British bucket latrines and incinerators were installed in them. Where there was no barracks the men lived in tents or bivouacs. Some few wooden huts were in use in Asia Minor along the shore of the Sea of Marmora and elsewhere.

The Russian barracks found in Batum and used by the British troops were of excellent construction.

The hospital permanent buildings at Batum were better than any seen elsewhere and the hospital huts decidedly better as regards ventilation, space and window lighting than any of those sent to Salonika.

The hospitals at Constantinople were put into Turkish barracks, the German civil hospital, or under canvas, the tents being gradually though slowly replaced by wooden huts of an improved pattern.

IN MESOPOTAMIA.

The question of hutting the force was first considered about the middle of February 1915. There were initially definite limitations as regards the materials to be used. The only possible materials of which the huts could be made were such as could be procured locally in large quantities in a short time, and in the use of which local labour could be employed. This at once eliminated brick and wooden huts. As the country had to a large extent already become flooded, dry earth could not be obtained in sufficient quantities to make mud walls. The local materials at hand were reeds, matting and wooden poles. The inhabitants were experts in constructing huts from these. The best type of hut used by them was found to be exceedingly narrow in the beam and otherwise unsuitable, especially as

regards light and ventilation. Three sample huts were then constructed and the type best suited to the troops was selected. It consisted of a reed and matting roof sloping on both sides from the centre, the apex being 14 ft. high. There were three layers of matting and a layer of reed, and for British troops there was an air interval between the second and lowermost layer of matting. The sloping roof ended at the eaves on both sides about 5½ ft. from the ground. The side walls were about 5½ ft. high and the top was about a foot from the inner surface of the eaves, so that there was an interval of about 9 in. between the slope of the roof and the top of the walls. The walls consisted of a lattice-work of reeds with a layer of matting on either side, and were provided with a certain number of doorways. On the west side an arched verandah was constructed. The floor was formed of boards raised 1 ft. off the ground. The rooms might be of any length, suitable to the plot available for building on, the breadth about 18 ft., and the height in centre 14 ft. The cubic space allowed per head was about 400 ft. and the superficial area 40 ft. In many of the huts ridge ventilation was provided. As far as practicable the general direction of the long axis was N.E. and S.W., so that there was constant perflation of air, the prevailing winds being N.W. and S.E. The lighting was only moderately good. These huts appeared to be the best that could be made for British troops under existing conditions and afforded sufficient protection from the sun. Their weak point was that of permeability to rain falling on the roof. By the time they were all erected, which was about the middle of May, the rainy season was over, so that their waterproof qualities were not seriously tested. For Indian troops, the structure was the same except that there were only two layers of matting on the roof and one on the side walls and ends. At the end of 1915, huts of this description took the place of the European pattern tents in the Indian General Hospital and in the extension of the British General Hospital, and replaced the general service tents of the other lines of communication medical units.

The hutting of the troops in Basra and Qurna was then almost completed, and was being commenced at Ahwaz and Shaiba. The military situation in these two places had not permitted the matter being taken in hand earlier. The materials were collected and ready to be used, and the huts only took a week or so to erect.

Shortly after the occupation of Qurna it was proposed to erect temporary barracks for one battalion of Indian infantry

and one company of Royal Garrison Artillery. The area available for the purpose was very limited. It was water-logged, and the building material was limited to wood or reeds with matting. Locally made bricks could be used, but to obtain a sufficiency would have taken some months. Eventually, however, reed and mat huts were constructed for the whole garrison of Qurna.

In 1915, at Amara, the troops were partly billeted, partly hutted, the remainder being camped in European pattern tents. One British infantry battalion was quartered in the Turkish infantry barracks, the Turkish Governor's house, and in huts especially erected.

The Turkish infantry barracks were single storeyed, arranged around three sides of a large quadrangular space, the fourth side being a brick wall. The barrack-rooms were large and elongated, with an elevated brick platform on either side used as a common bedstead. Each room was intended to accommodate 100 men. The windows were provided with iron bars within, outside which the upper half was glazed, wooden panels closing the lower half. A good-sized verandah ran along the entire length of the inner side of the barracks. The barrack-rooms were very badly ventilated and lighted. It was necessary to make a series of large openings in the walls to act as inlets, and another series of holes in the roofs to act as outlets. The roofs were comparatively thin and consisted of a layer of mud resting on reeds and matting, the whole being supported by rafters. The latrines, which were built on the north-east corner, consisted of a series of squatting platforms leading to enormous cesspits. The whole barracks were in a highly insanitary condition and had to be thoroughly cleaned out and disinfected before the troops could occupy them.

The Turkish Governor's house, situated on the spit of land projecting into the junction of the Tigris river and Jahalah Canal, was a well constructed double storeyed edifice, and the best building in Amara. It housed about 200 British troops and some British officers. It was, however, badly ventilated; air inlet holes had to be made in the walls, and outlet holes in the roof, and it was necessary to use punkahs daily, during June, July and August.

Huts erected for the troops were of a good type. They had thick brick walls, a brick floor, and reed and mat roofs, with a good ventilation interval between the eaves and the top of the wall. All the other infantry units were billeted in large

grain sheds on the banks of the river and canal, on the outskirts of the town. Each shed consisted of a large quadrangular space surrounded by thick brick walls 12 to 15 ft. high. The shed extended inwards from the top of the walls and was formed of a roof of reeds, matting and clay, resting on rafters, the roofs being supported by rows of stout, wooden columns. The shed was completely open inwards. These sheds were very badly ventilated, so that it was necessary to make large windows in the walls 8 or 10 yds. apart, and two lines of openings 10 in. in diameter and 8 yds. apart in the roofs; the latter openings were surrounded by bricks set on edge or a mud funnel was formed as an improvised cowl to assist the up-draught of the air. These improvements made the sheds more habitable. As the sheds were mainly on the boundaries of the town there was no difficulty in obtaining ground for the various annexes. The great objection to them was the dust, especially during storms. This inconvenience was to some extent ameliorated by watering the area in and around the sheds.

Some of the best houses in Amara were used by a field ambulance. Another field ambulance was hutted in a date grove on the right bank of the river opposite Amara. The huts were of the type erected in Qurna, but with movable side walls. Three battalions of the infantry and a cavalry regiment were encamped in European pattern tents on the right bank of the river north and south of the river of Daffas, opposite Amara. Although the men used the date groves during the day, most of them slept in the open away from the groves at night. The village of Daffas and its immediate surroundings were in a very foul state; every roadway and almost every compound had been used as a latrine, and human ordure in every stage of putrefaction lay around. There were neither public nor private latrines, and dry refuse was strewn about promiscuously on the roads, lanes and in the compounds. The whole place had to be thoroughly cleaned up, and latrines and night-soil and refuse incinerators erected.

At Kumeit the troops were accommodated in European pattern tents on the right bank of the Tigris, about 700 yds. to the south of the village. It was an excellent site, dry, and covered with grass; its chief defect was the complete absence of any shade.

"Dugout" huts, especially at the British convalescent depôt at Amara, roofed over in various ways, were common up river. At Amara they were 6 or 7 ft. deep and covered with the

native pattern semi-circular reed and mat (*chetai*) roof. After 1916 all hospital huts were amply supplied with electric fans. No huts or buildings, however, could be described as comparatively cool except those constructed of bricks. Even the huts with movable frames fitted in the walls to allow of their being opened to the evening breezes were not entirely satisfactory.

In Baghdad the Turkish military hospital was taken and converted into a British hospital. It was a good hospital on modern lines, except for its sanitation. Nazin Pasha's house and *serai* on the right bank of the Tigris became the officers' hospital at Baghdad.

IN EGYPT AND PALESTINE.

During the period of defence of the Suez Canal line, and the long intervals which occurred in the subsequent advance through the Sinai desert, no buildings were available in which to billet troops, and enemy submarine activity in the Mediterranean prevented the importation of sufficient timber for construction of substantial shelter.

Hence, the majority of the troops were accommodated during this phase in bivouac shelters. Each man carried a canvas sheet and pole, each pair of men fastening their sheets together to form a roof, supported on the cord stretched over the upper ends of the vertical poles. Cover, weighing only 4 lb., was thus provided for two recumbent men. At their sides the canvas sheets were pegged down to the ground; mosquito-nets were provided later, which fitted inside the bivouac shelter, the one net protecting both men.

Double-walled bell tents, when available, provided accommodation in areas behind the front line. They also were provided with mosquito nets, as these became available, and when possible the tents were covered with an awning of matting. In some cases sufficient timber was obtained to form supports for shelters for from 6 to 12 men, the framework being covered by native matting supplemented by thick layers of grass on the roofs.

No better provision could be made while the occupied areas consisted of soft desert sand, but as the advance carried the force nearer the Palestine frontier, firmer soil made it possible for the men to excavate spaces beneath their bivouac shelters and bell tents. This increased their comfort not only in providing more space but also in reducing the temperature and excluding dust. Special ingenuity was exhibited in the excavation of kitchens, solid tables of earth being left well below ground

level but higher than the surrounding floor; the thrown-out earth was built up into shallow walls to support a roof of tarpaulin, and effectual protection was thus afforded during the dust-storms which, notwithstanding attempts at protection by means of wattle screens placed around cook-houses and messes, covered the food with fine sand, and were responsible for much diarrhœa. Firmer ground also permitted cool food-storage cupboards to be excavated in the walls of these semi-underground kitchens.

Despite these efforts to provide the best available protection, troops at this stage suffered considerably from inadequate cover in an area almost devoid of shelter from trees. In the interior of tents the temperature frequently rose to 115° F. There was no spare water to cool them by wetting the walls, and it was frequently impossible to obtain materials with which to make matting to place over the tents and bivouacs. Contrary to expectations, the men suffered as acutely, though for shorter periods, from the intense cold of the winter rains and the penetrating damp cold of the mists, which night after night during early spring swept over the Sinai desert just before dawn, as from the heat. The troops were provided with woollen underclothing, serge uniforms, cardigan jackets, comforters and great-coats, and this warm clothing was then much needed.

Field ambulances had bell tents, with a proportion of Indian 120-lb. tents (double flies, on a ridge pole upheld by three bamboo uprights sloping to walls 2 ft. high). They had also the British pattern operating tent. Casualty clearing stations and stationary hospitals were provided with European pattern Indian tents. Base hospitals were mostly in permanent buildings in Egypt, in barracks, schools and pre-existing hospitals enlarged or adapted for the purpose.

Later, during this stationary period, wooden huts of various patterns were imported and utilized for messing, recreation and office purposes.

During the period of advance through Palestine and Syria, owing to transport difficulties, no shelter other than the men were able to carry for themselves was provided except at long intervals, hence bivouac shelters still formed the only protection for the bulk of the troops; while during the great advance even these were dispensed with owing to the need for extreme mobility. This, was, however, of little importance as the advance commenced on the 19th September, when the temperature was neither too hot nor too cold.

Bell tents were brought forward as rapidly as possible for use on the lines of communication and by garrison units.

The tentage of medical units remained as before. Indian E.P. tents were also used in the large General Headquarters camp near Ramleh.

There were few buildings sufficiently large to accommodate any considerable proportion of troops, but good accommodation was secured for some of the headquarters of larger formations. When Jerusalem was captured more buildings became available, especially for hospital purposes, but the city lay too far east of the main lines of communication to make it possible to use the accommodation fully until later. The English, French, Russian and German hospitals were taken over; the Russian Hospice served to accommodate troops; and the Victoria Augusta Hospice on the Mount of Olives provided accommodation for a corps headquarters personnel and offices. A deserted monastery at Latron, and larger buildings at Ramleh and Jaffa were also utilised during the long pause which preceded the final attack on the Turkish defences north of the Jerusalem–Jaffa line.

During the period between the great advance and the armistice the troops were distributed throughout Palestine, Syria, Cilicia, and part of Kurdistan, often being broken up into small detachments garrisoning the lesser towns. Owing to the insanitary condition and malarial infection of nearly all towns, the troops were kept under canvas as far as possible, mosquito-proofed huts being provided for messing and recreation and all personnel sleeping under individual mosquito nets.

Turkish barracks, the more modern of which—such as those at Adana, Hama and Aleppo—were of good construction and on healthy sites remote from the insanitary town areas, were utilized to their maximum capacity.

Amongst the most important of other large buildings occupied were the colleges at Tarsus and Marash; the mills at Mersina; the mission premises at Aintab; the aerodrome at Muslamie; gendarmerie quarters at Nazareth; hospital at Urfah; hotels at Baalbek and Ain Sofar; a convalescent home at Zahle; and the Russian hospice at Jerusalem. Extensive use was also made of quarters and other buildings at many railway stations.

Where troops were compelled for military reasons to live in the towns, private houses were selected in the least insanitary areas, and were mosquito-proofed as rapidly as possible.

Use was made of existing hospitals in which to establish the medical units. When all areas north of Palestine were evacuated, a large central hospital was established at Ludd, for which

purpose there was designed a special form of hut with double walls enclosing an intervening air-space (each wall being formed of cement poured between layers of supporting material nailed to wooden uprights), and with double roofs perforated by vertical outlet ventilation shafts. Verandahs were also provided of sufficient width to cover the beds of all patients at night.

IN NORTH RUSSIA.

The climatic conditions of North Russia demanded protection from the rigours of the winter months. All buildings, therefore, with the exception of small outhouses, whether in towns or in the smaller villages, were substantially built and provided with adequate warming arrangements. Whilst the majority of the buildings in Archangel were wooden, in the townships and the larger villages brick buildings existed and generally accommodated public offices and local administrative departments. It is probably no exaggeration to assert that no force during active service was so well housed as the troops occupying the arctic and sub-arctic territory. The towns and villages, however, were frequently housing more than their usual number of inhabitants, since refugees from the Bolshevik areas had sought cover in the northern districts occupied by the allied troops. Although housing was good, it was usually overcrowded and the arrival of the British troops increased the inconvenience.

The nature of the accommodation utilized for the troops may conveniently be considered under the headings of billets, barracks, rolling-stock, blockhouses and tents.

A large proportion of the troops, more especially officers, were billeted upon the inhabitants in their private houses. The private dwelling most commonly used was constructed entirely of wood in one of two methods.

In the first class, practically in all cases the structure was erected on piles driven into the ground. On level ground the floor was about 2 ft. above the underlying surface. The walls consisted of long thick logs, roughly prepared from large pine trees, usually about 23 ft. long and about 6 in. thick, since these dimensions allowed of convenience in handling. The opposing surfaces of the logs were facetted or levelled by the axe. Opposing ends of logs were fashioned also, so as to fit together securely. After the walls were erected, the seams between each layer of logs were packed with flax or jute, with the aid of a cold chisel. The floor was also made of logs, over which a layer of 2 in. of dry moss, sawdust, or

other suitable material was placed before the laying of the true floor with 2-in. planks. The roof was finished off in a similar fashion. Openings for windows were built or sawn out of the walls and fitted with glazed double window frames. The doors were double, close-fitting, and frequently covered with felt. In most houses, the "closet" was situated in the space between the inner and outer doors, although in larger buildings it might be found in a wing of the house especially constructed for this purpose.

In the second class of dwelling, after the floor had been laid on piles, the walls of the house were built so as to be double. Two-inch planks or ordinary bricks were used, and the inter-space of several inches packed with earth, sand, or sawdust, so as to conserve the heat within the building. Otherwise, the plans conformed to those of log buildings.

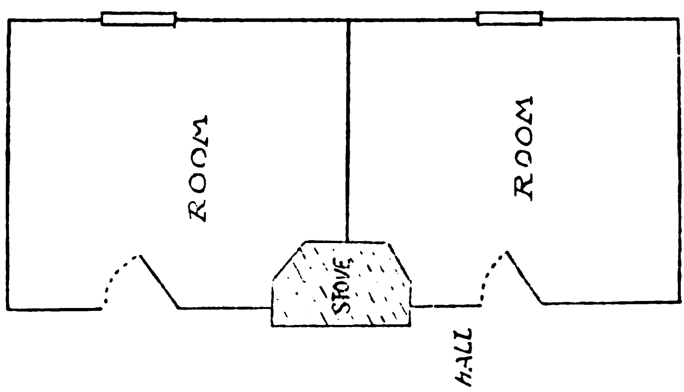


Fig. 18.—Stove for heating simultaneously the hall and two adjacent rooms of a house in North Russia.

The larger buildings, as, for example, those in Archangel, had, in addition to the kitchen, several rooms used as living-rooms and bedrooms. The rooms were usually commodious and lofty. Russian families apparently preferred to live in the kitchen, the reception rooms being reserved for special occasions, and it was for this reason that billets for officers and men were at first comparatively easy to obtain.

Except in the very large and more modern buildings where central heating was adopted, in all cases the method of heating was similar. A large brick, heat-retaining structure was installed during the course of erection of a house. It was placed so as to supply heat to two or three adjoining rooms,

and the walls of the stove were arranged in such a way as to present a large portion of heat-radiating surface to each of the rooms. Fig. 18 shows a common arrangement provided for the heating of the hall and of the two adjacent rooms on the same side of the hall as the stove.

The stove was a brick cylinder or rhombohedron, having an internal diameter of about 2 or 3 ft., and reaching from floor to ceiling, where by a flue it merged into the chimney. The brick floor of the stove was about a foot above the floor level, and the fuel was inserted into the interior through an orifice, roughly a foot square, secured by double metal doors. At the top of the stove, near the ceiling, an arrangement was inserted by which a flue might be closed or opened.

In ordinary circumstances the stove was lighted once every twenty-four hours. Wood logs, 2½ ft. by a few inches, were inserted and piled cone-wise in the centre of the floor of the stove. A handful of wood spills was ignited and applied to the centre of the log pile. The flue was opened and the logs rapidly kindled. When the embers were glowing, these were broken up and carefully spread over the floor, the flue closed, and the bottom door sealed. The confined heat became absorbed by the brickwork of the stove, which in its turn radiated heat in all directions. The temperature of the rooms now rapidly rose and was maintained at 70° or 80° F. No further attention to the stove during the following twenty-four hours was necessary. Next day the stove was cleaned out and re-lighted.

Barrack-rooms were provided with stoves of a similar type, resembling large metal cylinders, which were placed in different portions of the room, sometimes down the centre, sometimes at each of the four corners, and sometimes both at centre and corners.

For small, single-roomed dwellings a much smaller type of stove was used, made of sheet iron and lined with fire-brick. The method of lighting was similar.

A Russian building had practically no proper ventilation. The house was designed with the definite intention of reducing to a minimum the dissipation of heat, and it must be admitted that in this respect Russian ingenuity had met with success. The windows were double-sashed. The inner sashes, however, were removed in summer, and the outer sashes opened when the weather appeared favourable. But in winter, ventilation by means of windows was effectively prevented. It was also unlikely that air percolated through the outer walls.

In certain instances some effort had been made to arrange for the change of air in a room. An air exit was sometimes provided in connection with the stove in the form of a circular aperture communicating with the flue above the damper. Sometimes a small rotating fan was fixed in the lumen of the aperture. In the outer wall of the room, and as nearly as possible opposite to the stove, was another circular aperture of about 1½ in. in diameter, which was closed either by a movable accurately fitting wooden plug, or by a cover opening automatically. The aperture communicated directly with the outside atmosphere. When change of air was considered necessary, the aperture in the wall was uncovered and the movement of the fan in the air exit became discernible.

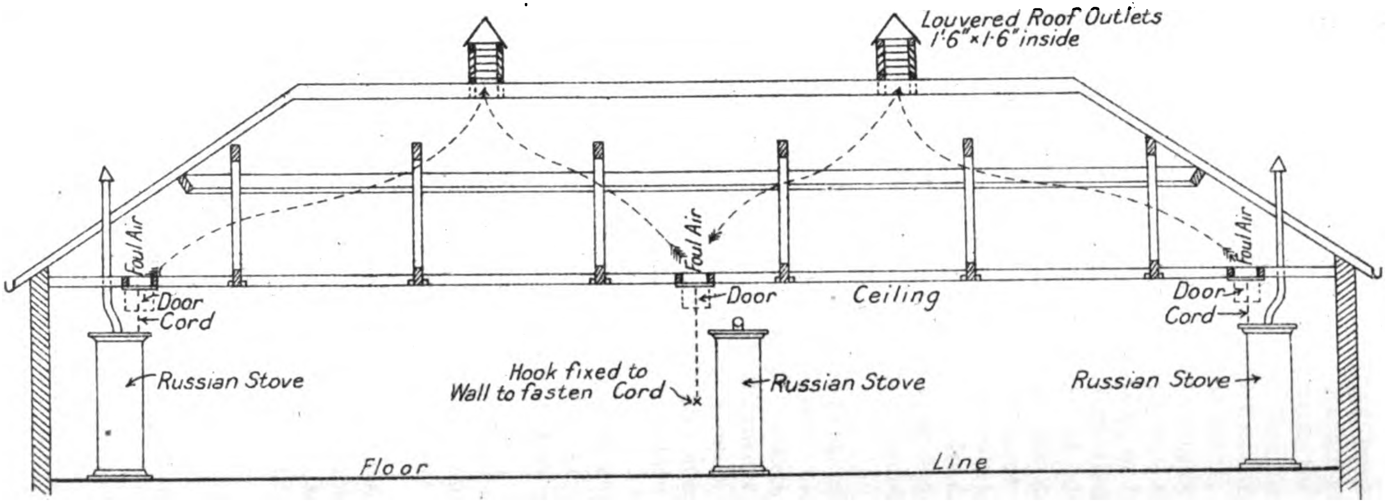
During the winter months the rooms were in no way air-flushed. The opening of the entrance doors of the house did not permit access of air since the outer door closed, as a rule automatically, before the inner was opened. In few houses were open fire places encountered.

The Russian beds were rarely, if ever, used by the troops. Officers preferred their portable beds, and the men were supplied with palliasses, straw and blankets to spread on the floors. Occasionally the Royal Engineers were able to improvise beds of wood and canvas. Houses which were taken over in the forward area and on sleigh routes were "bunked" in many cases by the engineers with a view to increasing the comfort of the troops.

It was necessary to provide rest-houses with accommodation for officers and men at each stage of approximately 20 miles along sleigh routes. In most cases, village houses were taken over and bunks installed in them.

Troops were frequently housed in large buildings such as schools, technical colleges, and local administrative offices. Such accommodation was always admirable and under British control was adequately ventilated.

Archangel, its environs and Murmansk had been well provided with naval or military barracks, large wooden buildings so arranged that each separate building allowed sleeping accommodation for approximately two hundred persons. The ceilings were invariably high, and advantage was taken by the Russians of this fact to increase accommodation to an extent greater than floor space would, from the point of view of comfort, permit, each person having 20 sq. ft. of floor space. The increased accommodation was obtained by double bunking. The lower bunk was 2 ft. above the floor and the upper



LONGITUDINAL SECTION.

FIG. 19.

SCHEME FOR EXTRACTING FOUL AIR FROM BILLETS.

(SUITABLE FOR WOODEN BARRACK HUT, N. RUSSIA.)

Malby & Sons, Lith.

bunk 4 ft. immediately above the lower. The bunks were simply wooden platforms often without side or end protections. Warming was effected by several cylindrical stoves distributed throughout the barracks and the buildings were ventilated by throwing open the doors at each end of the building on several occasions during the day. The temperature was always well maintained at 56° F.

Efforts were made to some extent to effect ventilation of the barracks (Fig. 19). In the ceiling above each of the large stoves, small trap-doors were cut to permit of the extraction of foul air into the loft overhead. The trap-doors could be opened or shut by means of a cord running on pulleys. The vitiated air in the loft found its way to the outside through the wooden louvred ventilators usually to be seen on most Russian barracks.

Such barracks were, however, difficult to keep thoroughly clean since the bunks were fixed. The wood also harboured bugs with which many of the barracks were infested.

In certain situations and under certain conditions the only accommodation available for troops was rolling-stock of various kinds. Murmansk, a town already much overcrowded by civilian inhabitants and refugees, was a railway terminus. There a large quantity of rolling-stock, much of it long since unfit for its legitimate use, had accumulated. Indeed, when the original expeditionary force disembarked at this port, railway carriages and freight wagons in addition to one or two small steam yachts and several tents, offered the only immediate means of cover for the troops.

In the Archangel sector, whilst dwelling houses and barracks were more readily available, a portion of the force had to make use of rolling-stock. For that portion of the troops which was operating on the railway line from Obozerskaia in the direction of Emtsa, it was the only accommodation which presented itself, villages being few, small and widely distributed. At verst point 455, on the railway line, about 250 found protection in trucks and carriages. Headquarters staff occupied the saloon coaches containing bedrooms, sitting rooms and bath-rooms. Less pretentious and almost equally comfortable were the first-class corridor and dining carriages. There were also second, third and fourth-class coaches offering the corresponding degree of comfort in each case. All such stock was designed, however, to protect the passengers from low external temperatures. Most were sleeping cars. All had their own internal heating arrangements, hot-water pipes, the heat being generated by an ordinary

slow combustion stove at one end of the coach. The windows were double-sashed and ventilation was reduced to an absolute minimum.

In less fortunate circumstances, the Russian freight wagon, or *tepluschke*, was used. This was simply a closed truck having at each side a large sliding door. Such trucks readily lent themselves to conversion into comfortable dwellings. Small windows were constructed and small Russian stoves fitted centrally to supply warmth. The flue was led directly through the roof and arrangements were made to prevent outbreak of fire through overheating of the flue pipe. Each truck after being " bunked " by the engineers provided accommodation for 16 to 18 men. To meet winter conditions, however, the walls and roofs were lined with wood and the interstices packed with earth, sand, sawdust, or other suitable material. Small closely fitting doors were inserted at one or other end, and the large sliding doors sealed up.

With the assistance of the Royal Engineers, blockhouses were erected for defensive purposes at the selected portions of the Archangel front. No standard type of blockhouse was adopted, as circumstances and conditions varied in different localities. Except along the railway itself the most common form on the Vologda front was one built of logs with walls 4 ft. thick, giving an area of 225 sq. ft. inside. The logs measured 23 ft. long by 6 in. thick. When the walls had been brought up 2 ft. above floor level, the log floor was laid, covered to a depth of 2 ft. with moss, and then covered with the true floor of 2-in. planking. The spaces between the logs were well filled with moss and earth. The roof was sloping and made of splinter-proof logs, covered with 2-in. planking and finished with roofing felt. The house was fitted with a stove and bunked for eight men. Logs were plentiful in the forests, and, as a result, in the Vologda force, this type of house was evolved.

On the river front, where sand was usually available, the most common type was one consisting of two single log walls with 3 ft. of sand between. The roof was made of splinter-proof logs, covered with sand, and a double slope roof was erected above.

Generally speaking, accommodation in tents was rarely adopted. In summer, at Murmansk, tents were erected for a company of Royal Engineers. It was a matter of much difficulty to select a suitable camp site on *tundra* or marshes where moss was so deep and bog water so frequent. On the

tundra, too, both during the hot day and unshaded night, the gnats or mosquitoes became intolerable. Tents were also pitched on Murmansk quay to relieve temporarily the congestion of rolling-stock and transports.

It was rarely possible anywhere to arrange for separate mess-room accommodation. There was a central mess in Archangel for men attached to General Headquarters. At Economie the large Russian barracks included a commodious room in direct communication with the kitchen which served admirably as a mess-room. In the great majority of cases however, food had to be consumed in the sleeping quarters.

The standard of comfort enjoyed at the base diminished noticeably towards the forward areas where accommodation became scanty. At relay posts, too, on the lines of communication, men and Russian sleigh-drivers slept side by side, a circumstance which would have rendered the control of a typhus fever outbreak one of great difficulty.

Archangel, Bakharitza, and Murmansk had an electric light and power supply, generated by steam turbines at power stations, which gave satisfactory results. All billets and barracks were thus supplied and where new buildings for the troops were erected, no difficulty was experienced in providing adequate illumination by wiring from the town supply.

Outside the base, oil lamps and candles had to be used, and only when the arrival of necessary supplies was delayed for transport reasons was discomfort in that respect experienced. During the early months of occupation, however, the advanced forces were ill-supplied with lighting requisites, and much avoidable depression was the consequence. As supplies from England arrived, this state of affairs was quickly rectified. Later, through the efforts of the Royal Engineers, electric lighting sets were installed at troop centres along the lines of communication, and the necessary wiring to hospitals, etc., was begun before the beginning of winter 1919.

CHAPTER XV.

THE CLOTHING OF THE SOLDIER.

CLOTHING plays an important part in maintaining the physical fitness of the soldier and his powers for marching and fighting purposes. Not only by reason of its nature and design, but also by its undue contribution towards the weight of the total kit borne by the soldier, it may disturb that equilibrium between equipment and mobility which counts for much as a factor in military success. The problem, then, is to provide clothing which, while meeting the demands of hygiene, shall at the same time be as light and as little restrictive of free movement as possible.

The history of military clothing is not without interest. The clothing of the Roman legionary comprised a woollen tunic, a leather doublet, and a russet cloak. In cold countries he wore *fasciæ* (primitive puttees); otherwise his legs were bare, save for the heavy sandals which served to protect his feet from injury. Thus he was lightly clothed and not hampered in the exceptional output of physical energy which his method of fighting entailed.

In the Middle Ages there does not appear to have been any general effort made to standardize the soldier's clothing; but in Elizabethan days there was progress towards a uniformity in the jerkins, coats, vests and skirts then worn. It was left to Cromwell to clothe his men on standard lines; but like the soldiers for many years to follow they were awkwardly clad in heavy, cumbersome articles.

Throughout the 18th century the design and colour of the uniform and the variety of facings and ornaments in most European armies made a display which was at variance with utility. By the middle of the 19th century military clothing, though still devised more for effect than for health, comfort and efficiency, and while taking little, if any, account of season and climate, received more consideration from these latter standpoints; and some of the objectionable features above referred to were eliminated.

In the more modern armies the physiological demands of clothing in different climates have been increasingly recognized, and such developments in the soldier's clothing have proceeded on more or less parallel lines in the chief military nations of

the world. Certainly the growing recognition of the importance of the subject has led to very material improvements during the past fifty years.

Thus it is now fully appreciated that the soldier's health and efficiency are intimately related to his kit; and that clothing which fails to protect the body adequately against heat, cold and wet, unduly restricts movement or interferes

Fig. 1.—Front view.

Fig. 2.—Back view.

Infantryman in marching order.

with any natural function, soon seriously reduces the fighting efficiency of an army. Warm clothing in cold weather not only protects against chill—a forerunner of much disabling sickness—but, as a part of food is utilized in the production of body heat, it also tends somewhat to reduce the physiological requirement of food. The chest in cold climates and the head and abdomen in hot climates are recognized as the parts more particularly in need of protection; and it is essential that the feet should always be well shielded from cold, damp and injury.

The soldier's clothing should be kept as light as is consistent with the purposes it is intended to serve. The aim is to maintain a proper balance between the total weight carried and his all-important marching powers ; for if he should reach the scene of action exhausted he may easily be beaten by an enemy inferior in fighting qualities and equipment. Of the total kit carried on the march the clothing now averages 12 to 14 lb.

Fig. 3.—Front view. Fig. 4.—Back view.
Infantryman in marching order.

The above requirements of the clothing equipment of the soldier received much consideration both before and during the war, and it was generally agreed that, varied as the demands were to meet the exigencies of season and climate in the different fields of operation, the British soldier was everywhere well and appropriately clothed.

The war was the first time a British army on active service in Europe wore khaki. Khaki represented an early expression

of efforts at concealing movements. Khaki clothing served in the war, as in South Africa and India, to provide a colour which is the least conspicuous on landscapes generally, and it had the added advantage of showing wear less than other colours. The absorption of solar heat being least with the lightest colours, the outer garments issued for use in the tropics were of a light yellow khaki tint.

Fig. 5.—Front view. Fig. 6.—Back view.

Cavalryman in marching order.

It was realized that the cleanliness of the underclothing is closely related to the personal cleanliness of the soldier. If the one is not maintained in a reasonably clean condition the other cannot be; and both are even more necessary to the soldier than to the civilian, because of the more intimate association of the former with his comrades. The neglect of personal cleanliness reduces efficiency by interfering with the healthy action of the skin and by favouring skin eruptions,

foot trouble and the harbouring of body vermin. Vermin led to discomfort and loss of sleep and indirectly to disease, and dirt favoured the septic infection of wounds. Hence it has long been the aim of military training to form habits of cleanliness in the soldier. The arrangements made for washing and bathing were as complete at all times as the circumstances permitted, and full use was made of them.

The many millions of articles of clothing provided during the war necessarily made a great demand upon industry and material, and to obtain the required output all articles were standardized; but in addition to the articles supplied by Government a very large number of hand-knitted woollen articles, such as socks, comforters and gloves, was provided by thousands of willing hands, working for the most part under voluntary aid associations.

The somewhat exceptional circumstances of the war often called for special provisions; departures in respect of clothing issues were made to meet these. As criticisms arising out of the practical experience of those who tested the clothing in all the circumstances and fields of active service throughout the war deserve consideration, efforts were made from time to time to collect such information.

Articles of Clothing.

Boots.—It is generally recognized that the soldier must always be well shod; a good boot is a considerable factor in maintaining his effectiveness. If it is not reasonably watertight the soldier may be invalided from those complaints which result, directly or indirectly, from wet feet in the colder months of the year; if it is faultily designed, badly made, or ill-fitting, an infantry man may become footsore and thereby rendered almost as ineffective as when wounded; and if it is unnecessarily heavy his marching and fighting powers may thereby be reduced.

While it was recognized that the early issue of the "overseas" boot was of good material and well made, the Army Sanitary Committee invited Lieut.-Colonel Kenwood, R.A.M.C., who was a member of the Committee, to consider and report to them as to whether, from the hygienic standpoint, the boot might be improved in design. Accordingly, Lieut.-Colonel Kenwood examined a considerable number of well-worn boots of the early "overseas" issue, and in collaboration with Mr. Charles J. Heath offered the following criticisms

and suggestions, at the same time submitting a specimen of an improved boot made from their design.

"(1) The early 'overseas issue' boot is too heavy; a pair weighs about 5 lb. 4 oz. Every ounce by which this can be reduced is of importance, because in marching a boot is raised over 300 ft. in every mile, and the dead weight when carried on the feet is many times more fatiguing than when borne on the shoulders. It should be possible to produce boots equally serviceable which will be lighter by half a pound than the pattern under consideration.

"(2) Whilst the uppers are of good, soft, durable leather, there are too many seams and these could be better situated. Every seam is a weak spot, and so unnecessary ones should be avoided. No seam should be placed quite close to parts which bend in wear, as the seam being of double leather and further stiffened by the stitching, will not bend; consequently the immediately adjoining single leather may do so acutely, and a sharp bend leads to cracking of the leather and consequent leakage. Further, the sharp bend of leather projecting inwards is liable to rub the foot and cause excoriations. In addition to being hard and unyielding, seams are thick and prominent parts of a boot (both inside and out), and if they be placed over the natural bony prominences of the foot they often cause excoriation and lameness. The vertical seams at the back of the boot under review project inwards and are liable to rub the heel or tendon, while the horizontal seam along the inner side of the boot will rub against the prominent tubercle of the scaphoid in men with flat feet.

"(3) The spot where the 'quarters' are turned from outside to inside is weak, and is not waterproof.

"(4) Where 'butted' seams are used (as just above the heel in this boot) they are hammered down to flatten them when the boot is 'lasted'; this causes the stitching to cut the leather at many of the stitch-holes.

"(5) The sides or quarters, and the stitching which holds them, reach quite three-fourths of an inch too far forward. They therefore impinge on a part of the boot where bending naturally takes place. Constantly recurring bending of a stitched part makes the stitches work loose, so that later the boot leaks, and finally the two pieces of leather come apart. The farther backwards the 'vamp' (the plain piece of leather over the toes) reaches above the instep the better, provided the boot can be put on easily and fits well round the ankle when laced up.

"(6) The extreme top of the upper is not thinned ('skived') down as it should be, where it lies against the leg under the puttees. There is no advantage but some disadvantage in a thick ridge of leather at this point.

"(7) Even if the boot is made at the height of this one (presumably on account of leggings or puttees) it should not lace so high. Time and material (in laces) are saved by avoiding unnecessary lace-holes; but the boot must lace snugly round the instep as well as close above the ankle. Six lace-holes on each side of the boot should suffice. Where the lace-holes are the leather should be stout and single; namely, without outer facing or inner lining. It would be well if the eyelets for the laces were set as far back from the edges as the attachment of the waterproof tongue will permit. It is important to make the boot (when laced) fit snugly round the heel and ankle. A good fit here is necessary to prevent the heel from lifting in walking and rubbing against the back of the boot, thereby damaging the hose, if not the skin.

"(8) The soles and heels are of good design; but the boot should be broader across 'the ball of the foot.' The average thickly socked foot, of a length to fit the boot under consideration, would scarcely find breadth enough in the tread; and here plenty of room is of primary importance. There is no suppleness or 'give' in the boot under review. It takes an enormous weight to bend it to any appreciable extent, and hence the plating and nailing of the sole is concentrated at the foremost part. The sole is too stiff at the 'waist,' and so it is only suitable for the stiff-footed few, and even these

latter would be as well off with a flexible boot. The waist of the sole should always be somewhat thinner that the tread; for here some flexibility of the sole is indispensable to proper walking. When this is present there is less friction between foot and boot, less wear and tear of hose, and excoriations are less frequent.

"(9) With reference to the nailing of the sole. The triple hob-nails used are unduly large and badly distributed for the purpose of resisting wear and preventing slipping. Smaller nails and many more of them should be used, and the metal plates, which weigh about ¾ lb. per pair of boots, done away with; for although these prevent wear, they are heavy and slippery. The main part of the tread of the sole upon which half a man's weight rests is not protected at all, either from wear or from slipping. The distribution of the nails in the heel is also faulty, and gives a bearing so narrow as to be but little more that half the width of the heel. The nails should be more uniformly applied to soles and heels. In the case of an abundantly nailed sole, the leather does not touch the ground when the boot is in use, therefore it does not wear away. (One of us has worn shooting boots for some ten years in which the nails have been added to on ten occasions, and the soles remain practically as good as ever.) By inserting more nails as those in the sole wear down, the sole-leather proves as durable as the upper part of the boot; not only is the life of the boot thus prolonged, but there is the further gain, that an old boot if maintained in a sound condition is more comfortable than a new one. As the hinder edge of the heel first touches the ground, this is generally the most worn part; here large, square hobnails, with long stems, should be inserted all round the bottom. When they wear down after much use they should be extracted, the holes plugged with wooden pegs, and new nails inserted. In this way the heels can be made as durable as any part of the boot.

"These considerations raise the question as to whether it would be practicable to make a nail issue to troops; the men being required to keep the nails on their boots up to the full complement, and weekly inspections made to see that boot efficiency and economy are maintained.

"(10) The lasts upon which these boots are made are not high enough at the toes. It is desirable that there should be a quarter of an inch more vertical space in this situation.

"Although in walking the weight of the body first falls on the heel and lastly on the front part of the foot (more particularly on the heads of the metatarsal bones), there is a stage when the whole of the weight rests on the sole and heel. Therefore the sole and heel of a boot should be made to rest flatly on the ground. The boot under review does not meet this requirement; for when the heel is applied flatly on the ground, the whole of the sole is slightly above it, and if the sole and heel are made to rest on a flat surface at the same time, it is only the front edge of the heel that touches the ground. It is obvious that if the toes of stout-soled boots are turned up, it is only when the heel is raised that the toes can be brought to the ground.

"(11) Finally, it may be added that before the soles are put on to the uppers all the stitching should be brushed with cold linseed oil, both inside and outside, and when finished, the whole boot should be immersed in animal fat at a suitable temperature. The leather is thus preserved and made supple, the stitches last as long as the boots, and the latter are much more watertight. Dubbin should be applied monthly during the cold wet months.

"(12) Foot peculiarities and deformities are numerous in adults. It is probable that the strictly anatomical foot is among soldiers the exception rather than the rule. Some classification of feet appears to be desirable to the end of securing the best fitting boots. This subject would repay investigation."

Lieut.-Colonel Kenwood's report, together with a boot designed to remedy the defects and carry out his suggestions, was subsequently submitted by the Army Sanitary Committee.

A meeting was then held at the War Office at which the Royal Army Clothing Department, the Quartermaster-General, and the Director-General of Medical Services were represented. A new type of army boot, which was then being issued, was shown in which the back of the upper was made in one piece, the centre of gravity was more in accordance with anatomical demands, the waist had some give, the uppers were skived, more vertical space was provided over the toes, and the vamp was carried farther backwards. It was agreed that the new pattern was a great improvement on the earlier issues, and that alteration of the seams at the sides, which required a double process of manufacture, as the two sides were not symmetrical, and the heightening of the boot, which necessitated more leather, were desirable, but could not then be carried out owing to the conditions of labour and supply. Nailing as suggested by Lieut.-Colonel Kenwood was also found to be impracticable at the time owing to scarcity of hand-wrought nails and the manual labour required. Raised block toes were stated to require an inner lining, which had been tried and discarded in consequence of the lining breaking after much wear; and when this happened repair was impossible, and the whole boot had to be scrapped. It was possible to get the same effect by means of an external toe-piece, but until the army requirements diminished very greatly it was considered impossible to carry out the alteration. But the points raised by Lieut.-Colonel Kenwood were noted for future consideration, when the necessary material and labour were available.

The boot subsequently issued was manufactured with the improvements recommended by Lieut.-Colonel Kenwood.

It was found that the army boot can absorb as much as one-third of a pound of water, and that in England it takes three days of wear before boots saturated with water become dry again. Yet the waterproofing of leather has certain drawbacks; it leads to the exclusion of air from the feet, and it may injure the leather when the waterproofing material is applied at a temperature about its boiling point. In this connection Captain H. Norman Goode suggested the use of hot "wood tar," such as is employed by shepherds in Scotland. The approximately 68 per cent. of pitch in this material supplies the waterproofing; and boots dipped into the boiling tar and then hung for two or three days are made quite waterproof. A few weeks' experiments with such boots furnished good results. The tar preserves the leather and the stitching,

and the use of dubbin and grease becomes unnecessary; and boots so prepared do not "draw" the feet.

The examination of chrome-tanned leather by Major Stanley Elliott disclosed the facts that the chromium in black service chrome leather appears to exist in the form of an insoluble chromium compound, and not as a chromate; and that the sodium or potassium chromate employed is rendered innocuous by treatment with sodium thiosulphate, whereby a harmless sodium salt is produced, which is not toxic to wounds.

Boots should be supplied in a sufficient number of sizes to make the securing of a good fit an easy matter to the men, among whom there is a tendency to select a size which is too small. It was represented in 1915 that the issue of new boots to units, two or three days before leaving England to join the army in France, had proved a marked source of temporary inefficiency in the First Army. All troops on the lines of communication (except reinforcements and mounted men) were provided with two pairs of boots during the winter months. Ankle-boots were issued in six sizes, each with three "fittings" (narrow to broad).

The issue of soles (inner) for ankle-boots was considered by the armies to be unnecessary during the summer, but opinion was divided with respect to their use in the winter months.

Many of the men expressed the view that for winter use the loose leather top boots, similar to those used by the German infantry, would be preferable to an ankle-boot as an issue to the dismounted men. It was maintained that these would be drier than the ankle-boot and puttees, and being loose-fitting would keep the feet warmer. Moreover, when muddy they are more easily cleaned than the ankle boots and puttees.

Mounted service field boots were first provided in France in 1915 for wear by mounted men as a better protection than the ordinary ankle-boot against the mud of the horse and artillery lines. Before the termination of the war, however, they were abolished, principally with a view to conserving the supply of leather. They were supplied also to troops in Italy and Macedonia.

Thigh gum boots were first provided for wear in trenches in France during the winter of 1915–16. Later on they were also supplied for Macedonia and Italy. They were issued, with inner soles, on the scale of 2,500 per division.

The prevention of chilled feet and frostbite was discussed by Brigadier-General Anderson and Colonel Horrocks, members of the Army Sanitary Committee, with the Quartermaster-

General, B.E.F., at St. Omer in November 1914. After visiting the front and seeing the first cases of frostbite that were brought into the casualty clearing stations, they came to the conclusion that prolonged wearing of boots in wet trenches and the constricting effects on the circulation in the feet by wet puttees were largely responsible for the cases of frostbite then occurring. They recommended that instructions should be given to loosen and readjust the puttees when men were in wet trenches, that a second pair of socks should be carried in the overcoat pockets, and that men should take off their boots and put on dry stockings, the wet pair being dried over a brazier or other improvised source of heat. They also thought that well-fitting gaiters would be preferable to puttees, as they would not be so likely to interfere with the circulation in the legs. The issue of gum boots to men holding very bad trenches might also be advantageous, but the only effective way to prevent frostbite generally was to ensure free circulation through the legs and feet by frequent changes of socks and boots and massage of the feet.

A general routine order was subsequently issued embodying these recommendations.*

It was further ordered that under brigade arrangements, provisions were to be made for the washing and drying of feet in reserve billets; for dry socks to be exchanged for wet; if possible, for the sending of dry socks to the trenches; and for the drying and brushing of clothes.

Head-dress.—Early in 1915 the winter service dress cap was issued as more suitable than the staff service dress cap during cold weather. It was worn in France, Italy and Macedonia. Waterproof covers were provided in 1917 for wear over caps and bonnets as a protection against rain.

When the steel helmet was introduced in 1916 it became necessary to provide a cap which was easily portable when the helmet was worn, but which could be worn when the latter was not required. This cap replaced both the stiff service dress cap and the winter service dress cap.

"Curtains" were provided for caps in 1915 and for helmets in 1918, to protect the neck against the heat of the sun.

It was recognized that neither the stiff nor the soft cap was a perfect headgear; in fact, an ideal military headgear, combining hygienic requirements with smartness, has yet to be designed. The caps were light, but there was not sufficient air-space above the head, and the stiff cap as worn offered but

* See Chapter X, Hygiene of the War, Vol. II.

little resistance to the wind unless it was pulled too tightly and too far over the head. Moreover, the material was not rendered as waterproof as was desirable. Comfortable in cold weather, the caps were found to be hot in summer, and it was suggested that they should be freely provided with side eyelet holes for ventilation, and lined with Italian cloth. The men commonly cut out the lining provided in these caps during the hot weather. The soft wide-brimmed hat with a chin strap, as issued to colonial troops was, from most standpoints, the better head-covering.

In Macedonia and other Mediterranean theatres of war and in the Eastern theatres of war, the Egyptian or Indian helmet was worn. It was at first doubtful whether it was necessary to provide a different head-dress from that in other parts of Europe for Macedonia, but it was soon found necessary in the height of summer to replace the service cap with the helmet of the tropics.

Coats.—The dismounted man's great-coat was heavy. When thoroughly wet it acquired an added weight of some 6 lb.—a material amount in addition to the already heavy equipment of the soldier on the march. It was, moreover, too long, and the buttons and tabs linking up the skirt were seldom used. In many cases the bottoms were cut off in the trenches, as they impeded movement and became very muddy. For these reasons it is not surprising that the great-coat was not popular. As a matter of fact, it was but little worn under active service conditions, and there was a considerable wastage in connection with this issue. In the opinion of many, a cardigan waistcoat, with a mackintosh cloak which could also serve as a ground-sheet, was preferable to an overcoat.

The "British warm" coats for mounted and dismounted services were much appreciated by the troops. Lined sheepskin coats were first issued in 1916 for the use of drivers of motor cars and motor lorries. Originally leather coats had been provided for them, but were abandoned as they became too expensive and leather was required for other purposes.

Jackets.—The tight collar of the service dress jacket was very unpopular, particularly in the summer months when it led to much discomfort. By sealing up the outlet for the body sweat and hot air, it was far from hygienic, and when the collar was left open it gave a very untidy appearance. The open front, as in the officer's pattern and the khaki shirt with collar attached, were suggested as a preferable issue.

Large stout pockets were much needed to hold the numerous small articles which the soldier carried with him on the march.

Criticisms were consequently heard of the unserviceability of the bottom pockets, and it was suggested that these should be pleated on to the coats. The jacket was generally close-fitting round the hips even when the pockets were empty, and when they were filled, discomfort and unsightliness resulted.

Woollen vests or cardigans were also provided and issued throughout the war for wear during the winter months in France, Egypt and Macedonia.

As a protection against the cold experienced in France during the winter of 1914–15 fur undercoats were provided, but these were replaced in the following winter by leather jerkins, which were more suitable and could be more easily stored when not required. Leather is impervious to wind and by retaining a layer of warmed air around the body it retains the body heat to an exceptional degree. The issue was much appreciated, but the jerkins were often too large to offer the maximum of warmth and comfort.

Puttees.—The badly or tightly wound puttees restricted the action of the leg muscles in walking and so favoured fatigue, cold feet and frostbite. It proved uneconomical to issue the poorer quality material, which resembled ordinary khaki cloth, as this frayed badly.

Trousers.—A proposal made to substitute shorts for trousers during the summer months on the Western front was considered both from the tactical and medical aspects. While army commanders considered the issue, as an additional garment, desirable, they were unanimous in saying that shorts could not be added to the already heavy kit the soldier had to carry, and to be of use they would have to be with the man and not with the transport. There were also the additional objections that the knees were exposed to the effects of poison gas, and would be more liable to injury from the cuts and abrasions caused by barbed wire, and that shorts would not afford sufficient protection from cold at night. It was therefore decided that shorts should not form part of the summer scale of clothing in Europe, either in substitution of or in addition to trousers.

Socks.—Three pairs of woollen socks were issued to each man. The comments of some of the men upon this issue were to the effect that too little attention was paid to the provision of the proper sizes, that out-sizes were rarely available, and that insufficient efforts were made to match the socks properly after they had been washed.

The proper size of sock is a matter of great importance, as regards efficiency in marching and the avoidance of foot

trouble. Socks must be thick and soft when a heavy, hard boot is worn. A hole in a sock often led to excoriation and blistering of the skin, while its repair by bad darning caused similar troubles.

The soldier's "housewife" contained needles, threads, and buttons only. It was a useful first-aid outfit for his clothing, the more serious injuries being referred to the regimental tailor. The issue of a "housewife" raised the question of whether the principle of self-help by the soldier could not with advantage be extended in other directions. For instance, it was suggested that an issue of a few screw nails might be made to replace the sprigged nails when these fall out or wear down, but it was felt that the maintenance of this nailing of the soles and heels of boots was a matter of such importance from the standpoint of efficiency that it should not be left to the soldier. Pairs of nailed, sprigged soles of suitable sizes were issued in considerable numbers, and these were fixed, mostly to re-issued boots, by the regimental cobblers.

Special Articles of Clothing.—In addition to the articles detailed in the scale for the various campaigns, a number of special articles was provided for protection, principally against cold and rain, and also against excessive heat, mosquitoes and other insects. They were sent in bulk to the various theatres of war, and issued as required.

Although body bands had been reported upon unfavourably by the medical authorities a short time before the outbreak of war, and had consequently been discontinued, they were reintroduced in the winter of 1914 for wear in France, on account of the warmth they afforded. The body band was, however, uncomfortable to wear, and woollen belts superseded them at a later stage. There was a unanimous opinion that body bands did not contribute either to comfort, warmth, or health. The men themselves disliked wearing these bands, as they harboured vermin. Ultimately, in 1917, they were again reported upon unfavourably, and their issue ceased.

Mackintosh capes were provided in the early stage of the war for wear in the trenches as affording better protection than the great-coat in wet weather. Subsequently a waterproof ground-sheet, which could also be used as a cape, was introduced and the mackintosh cape was abolished. A special cape with hood was provided for the troops in Mesopotamia in the autumn of 1916.

Woollen drawers were found to be too hot for dismounted men in France during the summer; consequently short cotton

drawers were introduced in 1916 for wear in hot weather. Owing to the cold experienced by kilted men during the winter, short drawers were obtained for the winter months in 1915–16 for those who required them.

Fingerless gloves were provided in 1914 for winter wear in France. They were provided with leather cords so that they could be suspended round the neck—following the practice in extremely cold climates.

Sweaters and gloves were issued during the winter months to railway guards and brakesmen who were greatly exposed to weather, especially on the main lines of railway.

The experience gained in the first summer operations in Macedonia in 1916 resulted in mosquito gloves being provided for future wear as a protection against mosquito bites.

Gloves were also provided for men handling barbed wire in offence or defence. They were first provided in 1916.

Eye-masks were first provided in 1916 for wear in Mesopotamia to protect the eyes against the glare of the sun and sand.

Men of labour groups employed in handling meat, when unloading meat trains, cold storage and meat ships, were supplied with canvas clothing overalls. Canvas suits were supplied to men working disinfectors and destructors. Special clothing was also issued to bakers.

Dungaree clothing was issued to A.S.C. units, and special clothing, which included sou'-wester hats, oilskin frocks and trousers, short and thigh gum boots, drill frocks and trousers, or canvas suits, as available, was provided for tunnelling companies.

There was a demand for khaki drill shorts during 1916 for wear in the hot weather by the troops in Egypt. Their issue was also extended to Palestine and Mesopotamia.

A pattern of khaki drill shorts which could be turned up during the day and turned down over the knee at night, as a protection against mosquito bites, was provided in 1917 for wear in Macedonia.

Lumbermen's socks were used in France as an additional protection for the feet during the winter of 1914–15, and were subsequently issued during the winter months throughout the war both in France and Macedonia.

Moleskin waistcoats were supplied in lieu of cardigan jackets for certain labour companies, prisoners of war escorts, employment and artisan companies.

Back pads and spine protectors had always been provided in peace for wear in West Africa as a protection against the

sun. The spine protector, which differed considerably from the back pad, although intended for the same purpose, was specially provided for wear in Mesopotamia in 1916. It was attached by means of a loop round the neck.

Mosquito veils were originally provided in 1917 for wear in Macedonia as a protection against mosquito bites.

It was suggested, as the result of experience, that in hot climates the wearing of coats and belts should be prohibited; that thin stockings should be substituted for puttees; and that a thin shirt tunic or blouse, open at the neck, should be worn.

Hospital Clothing.

Early in the war additional clothing and blankets for field ambulances and casualty clearing stations were approved, and included pyjama suits, bed-socks and warm bedroom slippers.

Men discharged from hospitals were reclothed by the unit in accordance with the scale laid down for the branch of the service to which they belonged, in order that that they might be ready for duty at once on rejoining their unit. Clothing was therefore kept in stock for this purpose by the various medical units.

Protection against Mosquitoes.

In Macedonia special issues were made for the personal protection of men from mosquitoes. Three varieties of mosquito nets were provided, with either a 16-in. mesh mosquito netting or a 22-in. mesh sandfly netting. These varieties were the bivouac net, the net for circular tents, and the hospital pattern.

The bivouac net consisted of a mosquito-gauze lining to the bivouac shelter when put up in the usual way. The net had no openings, but one end was extended outwards and supported from the guy-rope by metal rings threaded on tape sewn to jute webbing. This extension could be raised to admit of entrance, and automatically closed by its own weight. It was kept down by stones or sand placed in pockets at the lower border. Tapes held the net to the edge of the bivouac sheet. Jute webbing was used to strengthen rope connections, and canvas jute webbing or calico was sewn on at supporting corners and edges. Two men could lie lengthwise in the bivouac without touching the net.

The nets for circular tents made a complete inner lining in the tent. No opening was provided, enough slack being left

opposite the door of the tent to allow entry by lifting. Patterns with a lacing or buttoning entrance opening were found to be objectionable.

The hospital bell net was the conventional pattern for use in hospitals and other medical units, as well as in huts, houses, marquees, regimental aid posts, and even in bivouac tents and dugouts. Two or three men could sleep under one net.

Notwithstanding the modifications made, each of these nets failed in some respect or other under field conditions, but the hospital bell net was most generally serviceable and adaptable.

Gauntlets of finely woven cotton material were serviceable. They should be large, roomy, long, and capable of being fastened by tape or button to prevent slipping down.

The shorts already described, with a flap to turn down over the knees under the puttees, were also useful. The flap should be long enough to prevent its working out of the puttees, and should make a baggy cover over the knees.

Head-nets expanded on metal or cane rings of wide circumference, which drape the muslin well away from the head, were used. They should be of ample length to allow of being easily tucked in under the clothes at neck and shoulder, where they should bag and float free. They were made in slightly different styles for men and women, preferably of khaki-coloured mosquito netting. They could be made with mica windows, and also with a loophole or funnel for pipe smoking. Supported from above, this head-net could also be used in sleep as a miniature mosquito net.

The Washing of the Soldier's Clothing.

On active service troops usually washed their own clothing whenever a supply of water and facilities for drying were available, and many units followed this custom throughout the war. But owing to the nature of the warfare on the Western front, washing of clothing by men in the front line became impossible. The trenches, which in the earlier part of the war were occupied by a unit for fourteen days or over, could naturally afford no facilities for washing, and it was only on being relieved that the men had an opportunity of washing their underclothing. Accordingly, extensive arrangements had to be made for the regular issue of clean underclothing as frequently as possible, and for the washing of soiled clothing either by local contract—always a costly

proceeding—or at divisional laundries in suitable areas with civilian washerwomen.

Arrangements for drying clothes after washing always presented some difficulty in the field, especially during wet and inclement weather; drying-rooms were therefore constructed in all standing camps, convalescent depôts, base depôts, and reserve areas. They proved of the greatest value, tending not only to confer greater comfort but also to reduce the risk of contracting certain diseases. Thus, in laundries, where the temperature of the drying-rooms reached 80° C., the ova of lice which survived the process of washing were effectually dealt with.

As the number of men in the army in France increased it was considered that a large central steam laundry for each army area was better than divisional laundries, as affording greater efficiency, with economy in labour and expense. Accordingly, in 1917, army laundries were established in certain areas, where clothes sent down from divisions were disinfected, washed, and repaired. Eventually, laundries were established at Abbeville, St. Omer, Pont-de-Brique, near Boulogne, and elsewhere. Underclothing collected in divisional areas was packed in impervious canvas sacks and forwarded direct by rail, and on arrival was disinfected by means of current steam before being sent to the laundry, so that the destruction of vermin could be assured. The men employed in these laundries were chiefly prisoners of war, and the maximum output reached about 5,000 pieces per hour. Considerable difficulty was experienced in the disposal of the effluent from these laundries, since, in addition to its great volume, it contained an excessive quantity of soap, on account of the hardness of the water. Permutit filters were obtained to reduce this hardness, and a great saving in soap was thereby effected, and at the same time a greatly improved effluent resulted.

As a general rule soiled linen from hospitals was washed by contract, but in the later stages of the war washing was carried out at one or other of the large area laundries. A Government steam laundry was installed at Etaples in 1916, to deal with the large output of soiled linen from the many hospitals in that area. In the Second Army area a laundry organized by the R.A.M.C. dealt with the soiled clothing from casualty clearing stations.

Early in 1915, Major Ainsworth, commanding No. 1 Sanitary Section at Rouen, instituted a sanitary laundry at Bruyères Camp. It was found that among a large amount of discarded

clothing, which had been collected from the camps for the purpose of destruction, a considerable proportion could be washed, repaired, and made fit for re-issue. Arrangements were therefore made to establish a laundry, supervised by the sanitary section personnel and assisted by prison labour. The specialist sanitary officer at Rouen reported in 1917 that the number of articles washed and repaired, including bandages received from the local hospitals, amounted in six months to 232,110, and represented a saving of £7,273, and that the total savings in one year amounted to £11,945.

The experience of the war, therefore, proved the value of establishing laundries in the field. Not only was the washing of clothes by units themselves in great measure impracticable, but frequently the troops were in places where the necessary water supply was unobtainable. Further, in many instances, lack of time and opportunity made the regular and systematic washing of underclothes by the soldier himself impossible, and the inevitable result was an increase of disease due to unclean conditions.

Disinfection of Clothing.

In all theatres of war the disinfection of clothing and equipment was carried out on a comprehensive scale, and with the exception of certain articles of clothing liable to damage by steam disinfection, no practical difficulty was encountered. Clothing was disinfected or disinfested under the direction of the sanitary officers, either in the unit concerned or at central disinfecting stations established at railheads or at bases on the lines of communication. All clothing and effects of men admitted to hospitals were immediately disinfected in steam disinfectors, with which every hospital was efficiently equipped. The necessity for disinfection by means of reliable apparatus which would also ensure the destruction of spores was obvious. The clothes of men received from the front were covered in mud, often blood-stained, nearly always verminous, and liable to contain, from contact with the heavily manured soil of France, spores of tetanus, gas gangrene, and anthrax bacilli.

Disinfection was also carried out at ordnance depôts, which in many instances were provided with their own disinfecting apparatus. At the termination of the war all serviceable blankets, clothing and bedding were required to be disinfected before being returned to England.

In army areas, all clothing sent to the army laundries was disinfected by steam before being washed, and articles liable

to damage by steam were either dry-cleaned or disinfected by formic aldehyde when practicable.

Towards the latter period of the war, disinfestation by hot air became a practical method and articles which were liable to damage by steam could thus be treated without difficulty. It was found that with an exposure of twenty minutes to a temperature varying from 70° to 110° C. the fabric, either wool or cotton, was neither scorched nor in any way impaired.

Before being sent down by railway, clothing was sorted out into serviceable or unserviceable articles and packed into canvas sacks. All the clothing was carried in closed vans during transit, and underclothing was washed and disinfected under divisional arrangements before despatch.

Very complete and effective arrangements for the cleansing and repair of serviceable clothing were made at the ordnance depôt in Paris, which not only effected a great financial saving to the public, but also contributed largely to maintaining the health and efficiency of the troops. The general practice in regard to clothing received from the front was as follows:—

The clothing arriving by rail was first sorted out into (*a*) clothes worth repairing and (*b*) clothes not worth repairing. This sorting was done in specially arranged sheds, which were in no way connected with any other department through which the clothes subsequently passed.

The clothes considered worth repairing were sent in vans to certain selected laundries, in the neighbourhood of Paris, to which was attached a small ordnance staff whose duty it was to examine after washing all articles of clothing before their return to Paris. When received at the laundry the clothing was first soaked for a period of three hours in a solution of soap containing either 2 per cent. cresol or 1 per cent. formalin, at a temperature of 60° C. The clothes were then transferred to lessives containing a solution of soap and disinfectant, where they were allowed to remain for ten minutes before being finally washed in successive relays of clean water. They were then passed through a hydro-extractor before final drying in stoves at a temperature varying from 60° to 80° C. Such articles as leather jerkins were, for obvious reasons, not washed, but were cleaned in revolving drums containing hardwood saw-dust strongly impregnated with cresol and formaldehyde. Fur coats and sheepskin-lined coats underwent practically the same process. In some cases service dress was dry-cleaned.

After repair, clothes were carefully examined, particularly with a view to the detection of remains of lice and nits. Nits

even when dead adhered firmly to the fibres of the cloth and when detected were removed by means of wire carding brushes, which effectually detached them without damage to the cloth.

Cleaned and repaired underclothing was packed in sacking, a little naphthaline being added to each package, and despatched to the depôts. Service dress was made up into bundles and hospital clothing was packed in cases before despatch.

There was little doubt that the various processes to which the clothing was submitted during cleansing were sufficient to ensure that all lice and nits were effectually killed. Moreover, from the time the articles left the front until their return at least a period of from one to three months would supervene. This for all practical purposes would alone ensure safety as regards infestation.

Blankets were disinfected at Havre by steam before being washed, and horse-rugs were cleaned in revolving drums; the dust given off in the process being collected through ducts by means of an exhaust produced by fans. All blankets withdrawn from troops in summer were cleaned and disinfected at Paris before re-issue; and those used by the Chinese and Egyptian labourers, who were subjects of trachoma, were stored separately and kept for the use of trachoma labour companies only.

Considerable difficulty was experienced in disinfesting kilts by steam owing to the numerous pleats which harboured lice and their ova. Also the leather strapping of riding breeches was ruined by exposure to steam. Both these difficulties were overcome when hot-air disinfestation was introduced.

Disinfestation by means of steam often caused articles of service dress to shrink, and this was more noticeable in clothing worn in the later stages of the war than in that originally supplied. This was due to a certain extent to the use of an inferior material. Creasing of clothing also occurred when garments were packed into chambers in place of being hung, and the men generally resented this. When clothing was hung in the chambers such creasing did not occur.

Discarded Clothing.

Unserviceable clothing was clothing which was so worn that repair was impossible. Such clothing was sent to Havre for shipment to England.

All articles not capable of repair were sorted into woollen and cotton rags, packed in bales and forwarded to the base depôts for transmission to Dewsbury, where they were

sold by weight for re-manufacture. Clothing which was too foul to send to England was burnt in a destructor, and all blood-stained garments were destroyed. At one time it was thought advisable to disinfect all rags at base depôts before despatch to England. The Army Sanitary Committee, however, considered that this was unnecessary; and so, with the exception of clothing returned from hospitals, the rags were merely packed in bales, and no evil results were ever traced to this procedure.

In the event, however, of infectious disease being known to exist among the troops in any locality, measures were taken to prevent the despatch of any rags or clothing until after disinfection. Unserviceable clothing discarded by prisoners of war was generally destroyed.

As there was always a certain risk of the railway vans used to convey clothing becoming infected with lice, steps were taken to disinfect them immediately on unloading. This was carried out at first by the French railway authorities, but subsequently it was done by the British, who used a 5 per cent. solution of cresol.

CLOTHING IN NORTH RUSSIA.

The climatic conditions under which the force had to operate in North Russia demanded the supply of a special winter kit. The summer was short and frequently extremely warm, approximating occasionally to that of a sub-tropical country. Autumn and spring were equally short, and winter occupied the greater part of the year.

For the summer months the home scale of clothing was augmented by mosquito gloves and veils and woollen vests. In summer, so long as the sun was unobscured the heat was usually excessive, but with the advent of evening and a twilight which extended throughout the small hours the temperature fell rapidly, and woollen vests then proved invaluable. Mosquitoes were a constant source of irritation and annoyance. There was no respite from their attentions either day or night. Protection from their activities, particularly in the marshy areas where they abounded, was essential, and the provision of veils and gloves mitigated a real nuisance and danger.

The winter conditions, however, called for a much more extensive provision of protective clothing. The issue varied also in accordance with the nature of the work which the individual had to undertake. In this way there were three distinct scales of clothing. The following scale applied to

those whose duties confined them to the base or to certain sections of the lines of communication :—

Cap, fur-covered, white		1
Jerkin, leather, with loops and toggles		1
Muffler, long		1
Socks, worsted	pairs	2
Lumbermen's stockings, long	pair	1
Cap, Balaclava, special		1
Mitts, woollen	pair	1
Sleeping bag, skin-lined		1
Boots, Shackleton	pair	1
Goggles, yellow glass	,,	1
Gloves, fingerless, with gauntlets	,,	1
Coat, sheepskin lined		1

The cap was made of white, closely woven canvas cloth, lined with rabbit fur, and had ear-flaps similarly lined attached at the sides. A more closely fitting cap would have been more comfortable and less bulky than the one issued. Combined with a wind-proof hood, such a cap would have been certain protection from any temperature or wind. The woollen Balaclava helmet served as a head covering during sleep.

Leather jerkins were invaluable and permitted men to work in low temperatures, provided no wind was present, untrammelled by a cumbersome overcoat.

The muffler was as frequently worn without the overcoat as with it.

Lumbermen's stockings were large, loose and long, reaching well above the knee. They were for use with the Shackleton boots and were worn over the worsted socks.

One pair of woollen gloves was not a sufficient protection against the cold, and mitts were worn in addition. The mitts were put on first and then covered by the gloves, which had gauntlets to protect the wrists. The gloves being fingerless were easily withdrawn or put on and were usually attached to each other by a tape long enough to carry over the shoulders, a contrivance which tended to prevent the serious consequences of the loss of a glove. The mitts also fully enclosed the fingers, but to allow of freedom of the mitt-covered hands the index-fingers were given a covering separate from the other fingers.

The overcoat was made of a wind-proof material, lined either with sheep- or goat-skin. The sheepskin lining appeared to be the warmer. Men were expected to be supplied with coats which were long enough to cover the upper half of the leg below the knee. The coats were not supplied with waist-belts, but these were found to make the wearing of the coat more comfortable. Buttons or clasps were used for fixing.

Clasps were more easily fixed with gloved hands, but frequently broke. Serious defects in the build of the coats were the absence of lining in the sleeves and the fact that the sleeves were not impervious to wind. No more admirable coat could be wished for than the sheepskin *shuba*. Light, warm, wind-proof, and provided with ample skirt, it was most comfortable for sleigh-driving, and was the one used by nearly all Russian sleigh-drivers. Otherwise the coats used were satisfactory and were an excellent additional covering during sleep.

A special type of boot was designed for use in the North Russian campaign, and was apparently intended to satisfy all requirements. In structure it was a large-sized ankle-boot, leather-soled, with uppers of prepared, lined and closely woven canvas. The boot was fixed by means of broad tapes attached to each side of the upper, and crossed and wound round the leg. Not only was the boot very expensive, but it did not appear to be popular. The hard-polished surfaces of the soles tended to be treacherous on frozen snow. The unusual weight of the soles made the boots cumbersome and heavy, whilst the method of fixing was only suitable for a very light boot. On this account men complained after marching of tenderness and pain in the tendo Achillis. It was not, therefore, a suitable boot for marching, but possibly more fitted for long distance ski-ing. Indeed, for outpost or sentry duties, and for sleigh journeys, the Russian long felt boot, or *valenki*, was the most suitable and the most in demand. On the other hand, for marching, the Canadian mocassin was admirable, and whenever obtainable was used in preference to the boot issued.

The protection of the feet was a matter of serious importance. The prevention of frostbite was essential, and footgear had to be provided which would not in any way tend to diminish the supply of blood to the toes, and would allow the presence of non-conducting air spaces between the skin of the feet and the external atmosphere. Well-fitting socks, made of wool, were the best coverings, since wool contains a considerable amount of air in its meshes. Where several pairs of socks were worn they were of different sizes, so that one pair could fit into another readily without causing constriction. Lastly, the boot covering was pervious to air, otherwise moisture from the perspiration of the feet accumulated in the air spaces provided by the woollen socks. Rubber boots, for this reason, were most unsuitable. Frostbite was prevented by maintaining both warmth and dryness.

Sleeping bags were made usually of reindeer-skin and little more than large enough to accommodate the user. They were intended for use when warm lodging was unprocurable or uncertain, and on long sleigh journeys. While the bags supplied to the troops were perfectly satisfactory as a protective covering, difficulties were experienced in drying the interiors which became moist as a result of condensation. A bag, the interior of which could be readily dried, would have been a more suitable issue. For this reason the Canadian quilted pattern, which was made to open out completely, was a more practicable sleeping bag. Such a bag rendered the transport of a casualty less difficult, since access to the patient was then a matter of comparative ease.

These bags were not as a rule issued to troops at the base, since sleeping accommodation there was generally comfortable. However, when troops were sent to the forward areas or to stations on the lines of communication, bags were issued to each man to ensure protection both on the journey and at the forward billets.

Yellow goggles were worn as a protection against "snow blindness." Unnecessary to a great extent at the base, where the white glare was broken by the sombre colour of the houses, they were essential in the featureless districts where the trying glare of the snow was unrelieved.

When a detachment was intended to be mobile, some modification of the winter kit was essential, not only because sleigh transport was necessarily limited, but because it was also necessary for the men to be allowed as much freedom of movement as possible. The sheepskin-lined overcoat prevented the full and free movement of the limbs. Thus the skin-lined coat and the leather jerkin gave place to a woollen sweater, a woollen vest, additional pairs of drawers, several pairs of socks, so as to provide very frequent changes, and a set of wind-proof overalls, comprising blouse, trousers, and hood. So clad, the wind-proof hood covering the head enveloped in the Balaclava helmet, a man was able to attack, defend himself, or undertake the ordinary outdoor duties associated with service without danger from low temperatures and unencumbered by obstructive clothing. Cold feet invariably meant damp feet, the dampness being due to the condensation which took place within the boot. Men, therefore, were encouraged and ordered to change their socks frequently, and for this purpose a liberal issue of twelve pairs was allowed for each man. There was little doubt that the

strict enforcement of this practice prevented the occurrence of a larger number of casualties.

The following articles, therefore, formed the scale of clothing for a mobile force :—

Muffler, long		1
Socks, worsted	pairs	12
Lumbermen's stockings, long	pair	1
Cap, Balaclava, special		1
Mitts, woollen	pair	1
Sleeping-bag, skin-lined		1
Boots, Shackleton	pair	1
Goggles, yellow glass	,,	1
Gloves, fingerless, with gauntlets	,,	1
Sweater, woollen, R.A.F.		1
Vests, woollen, ordinary	pairs	4
Blouse, Burberry material		1
Trousers, Burberry material	pair	1
Hood, Burberry material		1

A third scale was given to what were described as super-mobile columns. It was but a slight modification of the mobile scale. Lumbermen's stockings and ordinary worsted socks were omitted, and different grades of thicker socks were substituted. The only difference, therefore, was that more care was concentrated upon the protection of the feet from frostbite.

There is little criticism in general that can be made of the efforts directed towards clothing effectively troops concentrated in an arctic or sub-arctic latitude. The remarkable rarity of frostbite as a cause of inefficiency, and the undoubtedly high standard of health during winter months are evidence of the suitability of the clothing issued to the troops in North Russia.

CHAPTER XVI.

THE HYGIENE OF TRANSPORTS.

THE hygiene of transports and the adoption of suitable methods to preserve the health of troops on board and prevent infectious disease being introduced into the United Kingdom, especially during demobilization, were matters with which the medical services were intimately concerned during the war. The reduction of shipping through the operations of enemy submarines, the large number of troops to be carried, the closing of the ship's port-holes in the areas infested with submarines, and the outbreak of influenza in pandemic form created many hygienic difficulties and necessitated the adoption of special precautions in order to prevent the occurrence of epidemic disease both in the bases overseas and in the training camps in England, where American and Dominion troops were concentrated before embarkation for theatres of war.

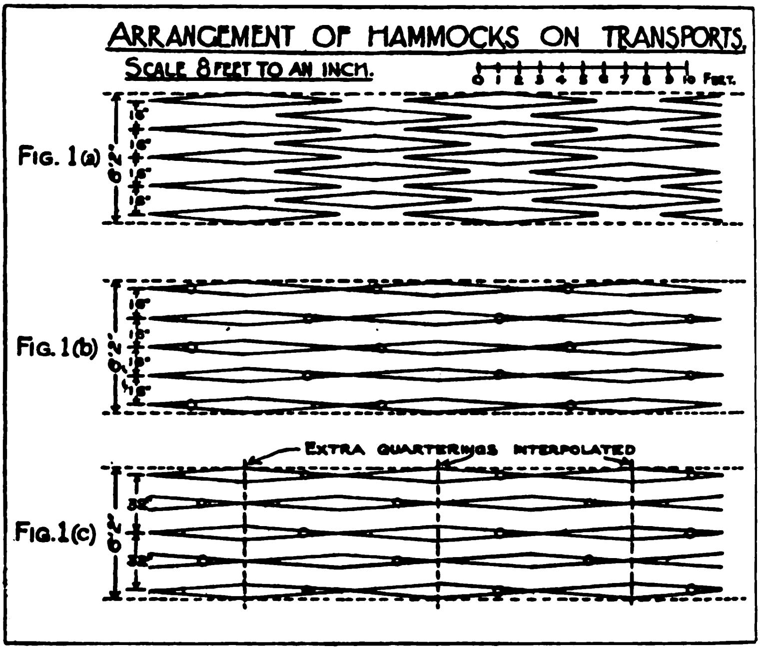
The specifications for the fitting up of ships were governed by the Transport Regulations, which existed previous to the war. The number of men to be placed on any ship depended upon the messing accommodation. The regulations were to the effect that every man must have a seat at a mess table, and therefore the maximum number of men a deck will accommodate was governed by the number of tables that could be fitted. The tables were to be of sufficient length to allow at least 20 in. for each man.

Some 20 to 25 per cent. of the troops embarked were not provided with hammocks; they were supposed to be on duty, but as a matter of fact only a small number of these men were really on watch at one time, the others slept during their off time in any odd corner of the ship. The hammocks were hung from hooks 16 in. apart, each berth being 9 ft. in length, locking in 18 in. at either end. The method is illustrated in Fig. 1 (a); the actual floor space, clear of all obstructions, per hammock was only about 10·5 sq. ft. and the cubic space about 80 cub. ft. Figs. 1 (b) and 1 (c) are explained on page 342.

In these circumstances the berths when occupied almost touched one another, and the heads of the men were very close to one another and well within the range of ordinary droplet infection from speaking or coughing.

There was no space between the sides of the ship and the hammocks which were slung fore and aft along the ship.

There was only one tier of hammocks in British ships. The hammocks were taken down during the day and stowed away; the tables were fixed and the hammocks slung over them at night. Certain ships, which formerly carried passengers, were fitted with a large number of third class berths. These were generally in two tiers, though some ships had three tiers.



Troops in hammocks had two blankets each. Cargo ships were supplied with mattresses and pillows, without pillow slips, formed of coarse sacking stuffed with straw or fibre, and these mattresses were removed from the ships after each voyage and burnt. The passenger ships were provided with bedding by the owners of the ship. As this bedding was of superior quality it was not removed from the ship at the end of the voyage, but when soiled was replaced by the owners on attention being directed to the matter by the transport officer.

Fresh air for the lower decks was mainly obtained by means of windsails; on the upper decks, which normally depend on ventilation through port-holes, extra ventilating fans were provided later on; most of these were worked by electricity though some were operated by steam power. The special ventilation arrangements provided by Transport Regulations

were mainly on the exhaust principle and consequently were likely to draw air from cooking galleys and lavatories into the areas used as sleeping places by the troops.

The proper arrangement of latrines and urinals had considerable influence on the health of troops on board ship. The position of latrines was on the upper deck where they could be easily accessible to men coming from the troop-decks. This might necessitate the latrines being divided into groups,

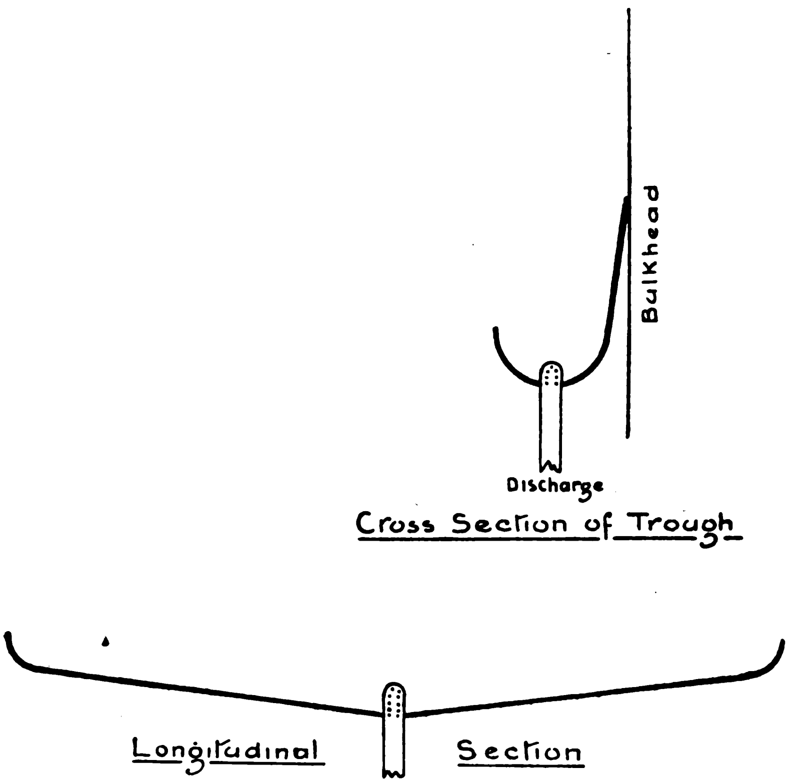


Fig. 2.

separated from one another. By regulations four seats were provided for each 100 men up to 300; two extra seats were allowed for each additional 100 men beyond that number; also two seats for non-commissioned officers. The requirements were that the compartment containing the latrines should not be less than 8 ft. high and 7 ft. wide; that the trough of the latrine should be semi-circular in section, with the outlet,

which should not be less than 6 in. in diameter, at its lowest point and with two bars across it to prevent choking. An important point was that there should be no angle in the discharge pipe. Each trough was to be flushed from either end through a pipe with a spreader, the pipe being connected with the salt water main and not less than 2½ in. in diameter. On sanitary grounds separate pedestal closets of the short hopper type were, however, preferable. The deck of the latrine was not to be sheathed, but painted or covered with granolithic. Urinals were fitted along the whole length inside the latrine on its in-board side. The best urinal trough was a rounded one of hopper type with no angles, sloping down to a 3-in. discharge pipe in the centre. Experience showed that a grating over the mouth of the discharge pipe insufficiently protected the pipe against blockage from matches, cigarette

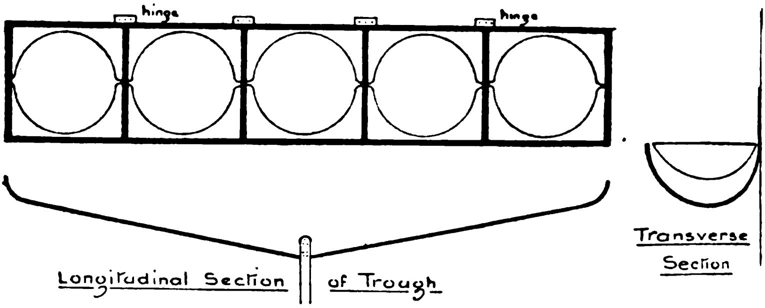


Fig. 3.

ends, and other matter. The most satisfactory fitting was a perforated dome (Fig. 2), the perforations being about ¼ in. in diameter. The back of the trough of this description should be carried up for at least 18 in. over the bulkhead.

For ablution, wash-basins were provided on the basis of four per 100 men. The following type was recommended as being more sanitary and durable than that usually fitted. Metal basins in groups of four or five were swung each on two pins in a metal frame, in such a way that the contents could be tipped into the trough beneath. The metal frame was hinged at the back to lift like a lid. The trough was of the hopper type and had no angles; it drained from its lowest point at the centre, where over the mouth of the discharge pipe was fitted a perforated cone similar to that recommended for urine troughs (Fig. 3). The advantages of this type were that there was no woodwork to become sodden or crack;

drainage was by gravitation and there were no stagnant pools of polluted water; the trough was open to the air and was easily accessible for cleaning. The whole system could be disinfected easily.

It was recommended that at least two showers (hot and cold water laid on) for every 100 men should be fitted in every transport, and that two canvas baths, each measuring 16 by 15 by 4 ft., should also be supplied.

On all transports there was a fresh-water supply for drinking and cooking and a sea-water supply for baths and sanitary flushing. A certain amount of fresh water was also supplied for ablution. The fresh-water supply was obtained from distilled water prepared on board the ship and also from a supply obtained from shore. The water obtained from the shore, usually a public water supply, was the main supply, and was relied upon almost entirely when the quality was good. Distilled water was used primarily for the boilers, but when the supply from the shore was insufficient or unsatisfactory in quality, distilled water was used either to augment the main supply or to replace it entirely. The Transport Regulations required that when there was a distilling apparatus on board water was to be issued on the most liberal scale. The minimum daily allowance for each individual embarked was 6 pints when out of the tropics and 1 gallon when within the tropics.

The fresh water was generally stored in compartments formed by the plating and framework of the ship, but it was important that their inspection manholes should not be placed in sleeping or messing compartments, and should not be flush with the deck.

Arrangements were to be made for filling the tanks without opening the manholes, and the tanks had to be ventilated. From the main storage tank the fresh water was usually pumped to gravity tanks, from which water was conveyed to all parts of the ship by a main which delivered into small storage tanks from which the distributing pipes were taken. Fresh-water tanks required to be inspected regularly and cleansed and cement washed every six months. It was rarely possible for the embarking medical officer to inspect the main tanks, but it was incumbent on him to enquire when they were last cleansed. It was also an important duty to make enquiries as to the source from which the shore water was being supplied, and, if it was a public supply, to ask for a copy of the bacteriological and chemical reports on its quality.

By making an examination of the amount of chlorine absorbed, using the water sterilization test case, by a sample of the supply before and after introduction into the main tanks, he could readily determine the condition of the tanks. If it should happen that the shore supply was open to suspicion and no other pure supply was available, then the shore supply had to be chlorinated when being delivered to the tanks. The capacity of the tanks being known, the amount of chloride of lime could readily be estimated by using the water sterilization test case.

The Transport Regulations provided for the fitting up of a hospital for ordinary cases and an isolation hospital for infectious cases on each transport. In the ordinary hospital two berths were fitted for every 100 men carried, including one swing-cot for every 200 men.

Mess tables were fitted for 60 per cent. of the berths in hospital. One bath with fresh and salt water and steam jets for heating the water was fitted for every 20 hospital berths, and one water-closet with salt water flush, and one wash-basin, for every 12 berths. A separate ward for special cases had to be provided.

A screened-off place for the examination of cases, dispensary, cot-lift, mess place for the R.A.M.C. orderlies, and a washing place for special hospital cases had also to be provided. The lightest and most airy place was to be selected for the hospital, and special attention paid to its ventilation. The bows and stern of a ship were unsuitable sites because of the excessive movement in these positions, and also because of the vibration at the stern. Experience showed that there should be 50 sq. ft. of deck area and 400 cub. ft. of space for every cot fitted in the hospital; that berths should be arranged in single tier, or double tiers in times of pressure; that all berths should be separated by a gangway 3 ft. wide with a main gangway 4 ft. wide, and that tiers of berths should never be erected alongside one another.

The position of the isolation hospital was on the upper deck in an isolated position. If possible, it contained two or more compartments. According to the regulations, the number of isolation berths was one for every 100 men, including one swing-cot to every eight double-tier berths. A bath, water-closet, and cabin for the attendants had also to be fitted.

A disinfecting chamber worked from the ship's steam was fitted in many of the large liners, but the essential requirement

was a chamber of simple construction, not necessarily for high pressure steam, on every ship carrying troops.* Experience during the war showed that a steam-tight chamber employing current steam could be constructed at small cost.

Inspection of Hired Ships.

According to the King's Regulations, a transport is a ship exclusively at the service of the Government on time charter, and a troop freight ship one in which conveyance is engaged for troops, but which is not wholly at the disposal of the Government. The regulations required that when a ship was engaged for the conveyance of troops an inspection of the fittings and arrangements for the accommodation and victualling of the troops had to be made prior to the embarkation by a board consisting of one or more naval officers and the military embarking staff officer. A medical officer at the station accompanied the board to give his opinion on sanitary points, and the medical officer who was to proceed in charge was also to be present if possible. This inspection was held as a rule where the first embarkation took place. A final inspection had to be held as soon as the embarkation was complete in order to ascertain whether the required arrangements for the troops had been properly carried out. The board of final inspection consisted of one or more naval officers and the military embarking officer. A medical officer, not proceeding with the troops, attended.

The forms on which these inspection boards submitted their reports during the war were drawn up by the Ministry of Shipping, and on completion were transmitted to the Director of Transport and Shipping.† Inspection reports were also furnished to the War Office by the embarkation medical officers who worked at the various ports under the Director of Medical Services for Embarkation.‡

From a medical point of view the first of the two inspections was of the utmost importance, so that any structural changes required might be completed before the troops actually embarked. The most important points were to ensure that the ship was not being overcrowded and that the decks were suitable for the berthing of men and adequately ventilated.

* All transports are now fitted with high pressure steam disinfectors.

† After the Armistice a new form of report to be signed by the embarking staff and medical officer was drawn up by the Directorate of Hygiene at the War Office.

‡ See p. 98, Vol. I of the General History of the Medical Services during the war.

During the war the question of sheathing decks in transports assumed considerable hygienic importance. The Ministry of Shipping required owners to sheathe iron decks with good deck planks. The upper deck exposed to the sun was completely sheathed, but on the troop decks only the gangways were sheathed, and foot-boards were laid between the mess tables. The deck under the gangways, where much debris collected, could only be cleaned with a hose—a state of affairs which was far from sanitary. Consequently, it was eventually decided that sheathing of troop decks should be dispensed with and that matting should be used for the gangways and between the tables. The matting was to be so put down that it would remain tight in its place as long as required, and could be easily taken up in order to cleanse the decks beneath. The men were also provided with rope or rubber-soled shoes to prevent them slipping an any exposed iron deck.

Measures taken during the Pandemic of Influenza.

The hygienic condition of transports was not ideal, but many thousands of troops were carried on board ship in the early years of the war without any very serious prejudice to the health of the men. The pandemic of influenza, combined with the necessity of closing ports owing to the submarine menace and the overcrowding of ships resulting from the military situation, led, however, to such a serious outbreak of disease, followed by many deaths from pneumonia, especially on ships carrying New Zealand and American troops, that a conference was held at the War Office in September 1918, at which the whole question of the health of troops in transports was thoroughly discussed.

As regards the New Zealand troops, the 40th Reinforcements were embarked in New Zealand on the "Tahiti," and the health of the troops was good until their arrival at Sierra Leone. Shortly after leaving the West Coast an epidemic of purulent bronchitis, with a very high mortality, broke out on board, and was attributed to contact with infected persons at Sierra Leone. A court of enquiry was held in England after the ship's arrival and a committee, called the Transport Epidemic Committee, was appointed by the New Zealand Government to enquire into the epidemic. This committee stated in their report that the "Tahiti," in respect of air space and other accommodation, was fitted out as well as or better than any other troopship, but the court of enquiry

reported that while the ventilation in the troop decks containing hammocks was satisfactory during the times that the ports were open, it was not satisfactory when the ports were closed during rough weather, at night-time, and during the period when the ship was passing through the danger zone. The placing of the hammocks 16 in. apart led to overcrowding. The only ventilation supplied was by means of port-holes and windsails, the latter being effective only in certain weather when the ports were closed. The court recommended that electric blowers or some other recognized form of artificial ventilation should be placed on all troop decks. The condition of the men quartered in bunks was not satisfactory, and it was suggested that the cabins should be removed and hammock fittings substituted. The court concluded that the high mortality was due to the virulent nature of the infection, which affected a large number of men massed together on a ship where the ventilation was defective owing to the enforced closing of the ports and the absence of any form of recognized artificial ventilation. The space per man on the different decks was as follows:—

	Cub. ft.
Forward, 'tween-decks	103
Aft, 'tween-decks	106
First saloon, on spar deck	87
Second ,, ...	148
Main deck, rooms alone	110
Poop	91
Boat-deck	72

As regards the transports carrying American troops, the "Olympic" arrived at Southampton on the night of 21st–22nd September 1918. The voyage had occupied only six days, and the ship carried 5,600 troops. General Winter, of the U.S.A. Medical Service, stated that on arrival there were 450 cases of influenza on board, and there had been one death. By 4 p.m. on the 29th September there had been admitted to hospital 1,947 cases, roughly 33 per cent. of the troops on board, and there had been 140 deaths.

In another instance a convoy of seven transports carrying American troops arrived at Liverpool and Glasgow. These vessels had been thirteen days on the voyage and 78 deaths had occurred on the high seas, and 600 patients had been taken to hospital in Liverpool and Glasgow areas. All the ships were overcrowded; one ship, the "Lapland," which had

formerly carried 2,900 Canadian troops, brought over 4,000 American troops. The experience of one transport, the "Empress of India," was instructive. The medical officer of the transport had insisted on all sick men being excluded from the draft, and in consequence 400 men had not been allowed to go on board. The ship carried 2,600 men and had only six cases of illness during the voyage. In the case of the "Olympic" and transports of the convoy, with the exception of the "Empress of India," no such wholesale exclusion of sick men from the drafts had been attempted at American ports of embarkation.

There were consequently two main lines, the one medical and the other structural, on which measures to improve the health of troops on board ship were directed for the prevention of diseases of a similar nature.* They may be summarized as follows :—

> *Medical.*—(1) Inspection of draft to secure that only healthy troops are embarked. (2) The prophylactic employment of an anti-catarrh vaccine.
>
> *Structural.*—(1) Arrangement of berths to secure sufficient floor space for each man so that he may be outside the maximum area of droplet infection from his neighbour. (2) Provision of sufficient cubic space to enable air to be renewed without the production of draughts. (3) Provision of sufficient fresh air, warmed in temperate climates and cooled in the tropics. (4) Provision of spray chambers and disinfector.

Medical Inspection of Troops prior to Embarkation.

The importance of not embarking men suffering from or incubating infectious disease was early realized by the medical authorities at the War Office, and instructions were issued to commands to secure adequate medical inspection of troops before embarkation ; it was also pointed out that leave prior to embarkation should not be granted to men who resided in districts where infectious disease was known to be prevalent. When influenza became generally epidemic in the British Isles it was obvious that troops could not be prevented from going to their homes without causing considerable hardship. It was therefore recommended that leave should be so arranged that troops might be under medical inspection in camps for fourteen days prior to embarkation. Special attention was directed to

* See also Vol. I, General History of the Medical Services, p. 319, for measures taken on board a Japanese cruiser.

the treatment of young soldiers. It was known that they were peculiarly liable to attack by certain infectious diseases incidental to camp life and life on board transports. Many of these young soldiers were drawn from rural populations which had not been rendered immune by infectious disease in the same manner as the urban population of large towns, and when attacked they offered but little resistance to these diseases. It was decided by the conference at the War Office in September 1918, referred to above, that a general policy should be followed in dealing with the young soldiers recruited in Canada, Australia, New Zealand, South Africa, and the United States. Whenever possible it was recommended that these young soldiers, on recruitment, should be received in camps and kept separate from other troops for a period of at least fourteen days. On arrival in camp they were subjected to careful medical inspection for evidence of infectious disease and when coming from districts where measles, mumps, cerebro-spinal fever and influenza were known to prevail, were to receive disinfecting spray treatment for at least three consecutive days.

Adequate inspection of the mercantile marine and civilians on transports was also of importance, and was normally performed by the medical officer appointed by the company under the direction of the master of the ship, according to the Board of Trade Regulations. In order to avoid any undue friction when dealing with civilians and mercantile crews of troopships, and to secure for the troops the best medical service, it was considered that the army medical officers doing duty with troops on transports should be specially selected, and that, so far as possible, they should be retained as transport medical officers. Also, inasmuch as transports differed materially in their arrangements, the transport medical officer should not be transferred from one ship to another if such transference could be avoided. Prior to the war the experience of the United States proved the advantage of having trained transport medical officers in the Philippine service, and this was also the experience with British troopships on voyages to India and garrisons overseas.

When transports arrived in port, it was considered advisable that any of the crew on board suffering from sickness notifiable or not under the Infectious Diseases Notification Acts should be removed for treatment on shore. In ordinary circumstances, naval and military cases were received into naval and military establishments, and cases of infectious disease among

the vessels' crews were dealt with by the local port sanitary authorities so far as their accommodation allowed. But there remained a class of case, such as men suffering from mumps and other ailments, which did not come under the terms of the Infectious Diseases Notification Acts, and adequate accommodation had, therefore, to be provided on shore for such cases. Unless some such steps were taken, it might happen that a patient on reaching port would be paid off and mix with the civil population or offer himself next day for service on an outgoing ship. Consequently, the Board of Trade and Ministry of Shipping were asked to make arrangements suitable for war conditions, for although the most careful steps might be taken to safeguard the health of troops on board transports, they might be of little use unless similar steps were taken to secure freedom from disease among civilians and crews on board.

Use of Anti-catarrh Vaccine on Transports.

Colonel Sir William Leishman submitted to the War Office conference a memorandum on the use of anti-catarrh vaccine for the control of influenza and other catarrhal conditions on transports. He considered that the vaccination of troops who were likely to be exposed to conditions such as had been reported was worth attempting. There were grounds for believing that it might be a useful measure, and there were none for considering it was dangerous. The most suitable mixture of micro-organisms in any particular instance must vary with the conditions under which it was employed; but, as a guide, Sir William Leishman quoted the following mixture, which had been employed with success by Dr. Eyre, of Guy's Hospital:—

	1st Dose.	*2nd Dose.*
Pneumococcus	50 millions.	100 millions
Streptococcus pyogenes (Hæmolytic variety isolated from cases of purulent bronchitis).. ..	10 ,,	50 ,,
B. influenzae..	10 ,,	30 ,,
Staph. pyogenes aureus ..	200 ,,	500 ,,
M. catarrhalis	25 ,,	75 ,,
B. pneumoniae	50 ,,	100 ,,
B. septus	50 ,,	100 ,,

At least two, and preferably three, doses should be given, and there was evidence to show that the most suitable interval between the doses was ten days.

For many reasons it was desirable that the course of vaccine should be completed before embarkation of the troops, for although it might be carried out on a long voyage, it was not possible during a short one, and, in addition, such conditions as overcrowding and sea-sickness were definite contra-indications.

The conference recommended the use of an anti-catarrh vaccine on the lines suggested by Sir William Leishman. Subsequently, when the epidemic of influenza began to assume formidable dimensions, a committee of bacteriologists met in October 1918 at the War Office under the chairmanship of Sir William Leishman, and advised a prophylactic vaccine for general use in the army of the following constitution:—

B. influenzae	60 millions	in 1 c.c.
Diplococcus pneumoniae ..	200 ,,	
Streptococcus pyogenes ..	80 ,,	

Two doses of ½ and 1 c.c. respectively were to be given at ten days' interval.

This vaccine was used with considerable success in the army, and was also employed in the case of troops carried in transports.

Structural Arrangements to increase Floor and Cubic Space, and Ventilation.

The adequate ventilation of troop decks was rendered extremely difficult during the war owing to the small cubic space allowed per berth and the general overcrowding of the ships. Fresh air should be propelled into the troop decks. The movement of the ship acts as a propulsive force in the case of windsails and shafts with cowls provided these are properly arranged. Latrines, lavatories, and cooking places, on the other hand, should be ventilated by extraction to remove the foul air and prevent it being drawn into the troop decks. Every part of a troop deck should be ventilated; if there are dead ends, namely, spaces extending horizontally more than 15 ft. beyond a perpendicular dropped from the nearest point of a hatch combing or from the opening of an efficient air supply shaft, then a special shaft or shafts, according to the space to be ventilated, should be taken down the hatchway and the air delivered against a bulkhead, or through a horizontal shaft perforated with holes placed close to the deck. A blower fan should be placed in each shaft. The ventilation of a troop deck is assisted by having an extraction shaft, the opening being at the highest point of the compartment, on the principle that fresh air should be delivered below the hammocks and

the foul air removed from the space above them. The amount of air supplied per head per hour cannot be exactly regulated unless the supply is completely controlled by mechanical means. Where a thermo-tank system is installed, as on some of the new large liners, adequate ventilation of all parts of the ship can be ensured, but such systems are not usually found on transports taken up for emergency service, or even for long engagements, and resort has to be made to special shafts and windsails. In barracks 3,000 cub. ft. of fresh air per hour are supplied for each man, but this is quite impossible in a troopship, where the cubic space is only just over 80 ft. Air might possibly be renewed fifteen times an hour if it were warmed in cold weather and so delivered as not to create a draught, but even then each man would only receive 1,000 cub. ft. of fresh air per hour.

The War Office conference consequently recommended that on the upper deck there should be placed large chambers fitted with steam coils over which the fresh air could pass to the troop decks, the warm air to be delivered close to the deck of the compartment and not overhead. The Ministry of Shipping agreed to do everything possible to improve the ventilation of ships by passing fresh air over radiators and introducing special shafts. The provision of increased floor and cubic space, though of the utmost importance from the health point of view, presented almost insuperable difficulties during war-time. As already noted, the Transport Regulations provided hammock berths for only 75 to 80 per cent. of the troops on board and the hammocks were slung from hooks only 16 in. apart, the available floor space per hammock being about 10·5 sq. ft. and the cubic space 80 ft. From the time of the Crimean War up to the commencement of the war in 1914, the cubic space per man in barracks was 600 ft. and the floor space 60 sq. ft., which allowed a space of at least 3 ft. between beds. After war was declared, owing to military exigencies and for financial reasons it was decided to reduce the floor space in huts to 40 sq. ft. for each bed. In the type of hut, 60 ft. by 20 ft., built in the early days of the war this caused a reduction of the space between the beds to 18 or even 12 in., according to the type of bed in use and the position of stoves. Experience of epidemic diseases, and especially of cerebro-spinal fever, showed that in these circumstances the presence of "carriers" and outbreaks of infectious disease were more common than under the old conditions and that merely separating the beds again to a distance of 3 ft. had a remarkable influence in

arresting infectious disease. It is not to be wondered at, therefore, that with only 16 in. between the heads of hammocks the health of men on board ship was far from satisfactory. Even in peace times, when ports could be kept open and men could be freely exercised and spend much of their time on deck, the increased prevalence on board ship of sore throat, tonsillitis, respiratory diseases, and minor septic diseases, which are indications of unhealthy conditions, as compared with barracks at home and at foreign stations, are shown by the following series of statistics.

Admissions per 1,000.

1911.	*Home.*	*Egypt.*	*South Africa.*	*India.*	*On board ship.*
Sore throat and tonsillitis	34·5	34·9	34·5	22·0	68·8
Diseases of the respiratory system	15·2	19·3	14·6	12·2	33·6
Minor septic diseases ..	33·5	40·8	28·6	44·5	94·9
1912.					
Sore throat and tonsillitis	30·9	46·6	35·6	22·6	68·8
Diseases of the respiratory system	15·9	13·3	12·1	15·0	50·8
Minor septic diseases ..	31·2	36·5	34·9	46·6	101·0
1913.					
Sore throat and tonsillitis	35·2	26·7	27·9	22·3	42·9
Diseases of the respiratory system	17·7	12·5	10·7	13·2	31·5
Minor septic diseases ..	34·0	32·2	27·6	40·4	111·7

If the principle were adopted that on board ship a man should have a clear space of 3 ft. between his and any other man's head, at first sight it might seem that this space could easily be obtained by putting the men in the hammocks alternately head and feet. Unfortunately, a practical test showed that this would be operative for only a certain number of men, and there very soon came a point where two heads would come close together. Moreover, soldiers object to sleeping in this manner, and in practice it was impossible to make them sleep "head and feet" on a crowded deck. (*See* Fig. 1 (b).)

The late Brigadier-General Sir F. J. Anderson, R.E., then chairman of the Army Sanitary Committee, was asked to visit a number of transports, as they varied considerably in their deck arrangements, and furnish a report on the accommodation for troops and make suggestions for its improvement. The following are extracts from his reports to the War Office:—

"The present scale of accommodation is that laid down in Regulations for H.M. Transport Service which I shall afterwards allude to as the 'Admiralty

Scale.' The accommodation provided is based on width of table 2 ft. 3 in. with central distance between tables of 5 ft. 6 in. and a table length of 20 in. per man, which amounts to an average deck area of 4·6 superficial feet per man. To this must be added the area of longitudinal gangways (not included in the above net figure), of hatchways, and of odd spaces, which do not lend themselves to the installation of tables. I believe that we shall not be far wrong if we say that the unusable area amounts, on the average, to some 75 per cent. of that actually utilized for seating accommodation (including the 3 ft. 3 in. between tables). Messing requirements thus involve an average deck area of $1\frac{3}{4}$ ft. by $4\frac{1}{2}$ ft. = say 8 sq. ft. per man, a reasonable figure for this specific purpose, as has been found in practice in the case of men's dining rooms in barracks.

" Assuming that the hammocks occupy the same area as the mess tables and that, according to laid-down practice, berthing accommodation is only provided for 75 per cent. of the troops carried, it follows that the normal gross area to a hammock is about 10·6 sq. ft.

" Fig. 1 (a) shows five rows of hammocks slung on the Admiralty scale, but I find that in practice the half-width of an occupied hammock amounts to 8 in. and not 5 in. as it scales in the diagram. The out-to-out width of the air area to be reckoned with is in this case 6 ft. 8 in., not 6 ft. 2 in. as figured. If X = the length of deck involved in feet and Y = the depth of the hammock line, expressed as the number of hooks involved, then the number of hammocks $= \frac{X(2Y-1)}{12}$, the net area per hammock gradually decreasing as the number of rows increases. The following table shows the net area for various numbers of rows and the average number of hammocks for every 100 sq. ft. of deck area actually occupied.

Number of rows of hooks at 16-in. centre.	Net area per hammock in square feet.	Average number of hammocks to every 100 sq. ft. of deck area.
2	$10\frac{2}{3}$	9·4
3	$9\frac{3}{5}$	10·4
4	$9\frac{1}{7}$	10·9
5	$8\frac{8}{9}$	11·2
6	$8\frac{8}{11}$	11·5
7	$8\frac{8}{13}$	11·6
8	$8\frac{8}{15}$	11·7
9	$8\frac{8}{17}$	11·8
10	$8\frac{6}{19}$	11·9
11	$8\frac{8}{21}$	12
12	$8\frac{8}{23}$	12
13	$8\frac{8}{25}$	12
14	$8\frac{8}{27}$	12

" It would therefore appear that the messing space per 1,000 men is, say, gross 8,000 sq. ft., whereas the hammock space for 750 (at an average of, say, $8\frac{1}{2}$ sq. ft. per man) is 6,375 sq. ft., the balance of 1,625 sq. ft. being allotted to between blocks of hammocks, etc.

" From the hygienic point of view, by far the most serious drawback of the Admiralty system is the lack of distance from mouth to mouth. I have worked out two methods of spacing out hammocks. Neither fully meets mouth-to-mouth requirements, but they each give 32 in. as compared with the existing 16 in. The system shown in Fig. 1 (b) possesses a slight advantage in that it involves no alteration in ' overheading,' merely requiring a slight staggering of the hooks, but, on the other hand, it necessitates men in alternate rows sleeping with their heads in opposite directions, and it is realized that this would be very difficult to enforce. The system in Fig. 1 (c) in addition to the slight staggering of hooks involves the interpolation of new ' quartering ' at 9-ft. intervals, but it allows of all heads pointing in one

direction and affords scope for much freer ventilation between the hammocks. As far as space occupied is concerned there is nothing to choose between the two systems. The following table shows the percentage reduction in the number of hammocks for different numbers of rows of hooks, as calculated theoretically in round figures :—

Rows of hooks.	Percentage of reduction in hammocks.	Rows of hooks.	Percentage of reduction in hammocks.
2	12	9	29
3	21	10	30
4	24	11	30
5	25	12	30
6	27	13	31
7	28	14	31
8	29		

"Practically a good deal depends on the actual length of deck space available. The following table shows the actual numbers of hammocks, under the three schemes, for various lengths of deck up to 99 ft., for rows of 5 and 8 hammocks respectively, together with the actual percentage of reduction in number of hammocks involved by the adoption of the systems shown in Figs. 1 (b) and (c).

Number of hammocks that can be slung and percentage of reduction involved.

Length of deck in feet.	Number of hammocks per 100 men with 5 rows of hammocks.					Number of hammocks per 100 men with 8 rows of hammocks.				
	Admiralty scale. Fig. 1 (a).	Scale A per 100 troops Fig. 1 (b).		Scale B per 100 troops. Fig. 1 (c).		Admiralty scale. Fig. 1 (a)	Scale A per 100 troops. Fig. 1 (b).		Scale B per 100 troops. Fig. 1 (c).	
		No.	Per cent. reduction	No.	Per cent. reduction		No.	Per cent. reduction	No.	Per cent. reduction
9	5	5	0	3	40	8	8	0	4	50
13½	5	5	0	5	0	8	8	0	8	0
15	9	5	44	5	44	15	8	47	8	47
18	9	10	—	8	11	15	16	—	12	20
21	14	10	29	8	43	23	16	30	12	48
22½	14	10	29	10	29	23	16	30	16	30
27	18	15	16	13	28	30	24	20	20	33
31½	18	15	16	15	16	30	24	20	24	20
33	23	15	35	15	35	38	24	37	24	37
36	23	20	13	18	22	38	32	16	28	26
39	27	20	26	18	33	45	32	29	28	28
40½	27	20	26	20	26	45	32	29	28	38
45	32	25	22	23	28	53	40	25	40	25
49½	32	25	22	25	22	53	40	25	40	35
51	36	30	16	28	22	60	40	33	40	33
54	36	30	16	28	22	60	48	20	44	27
57	41	30	27	28	32	68	48	29	44	35
63	45	35	22	33	27	75	56	25	52	30
69	50	35	30	35	30	83	56	32	56	32
75	54	40	26	38	29	90	64	29	60	33
81	59	45	24	43	27	98	72	26	68	31
87	63	45	29	45	29	105	72	31	72	31
93	68	50	27	48	30	113	80	29	76	33
99	72	55	24	53	26	120	88	27	84	30

"The result of the above proposals would be to increase the floor area per hammock from 10·6 sq. ft. to about 15 sq. ft. and the cubic space from 80 to about 110 cubic feet."

For hygienic reasons it was very important that every soldier on board ship should have his own hammock and blankets, as the communal use of hammocks and blankets undoubtedly led to the spread of infection. If every soldier had a hammock and Brigadier-General Anderson's scheme B were adopted, the reduction of troops carried on board ship would be more than 50 per cent. During the influenza epidemic a reduction of 50 per cent. in the number of American troops carried was allowed and this, with adequate medical inspection, was attended with the best results.

At a later conference held with the Ministry of Shipping, it was pointed out that such a reduction could not be maintained during the period of demobilization as it would seriously delay the repatriation of troops and entail heavy expense on the State.

It was then suggested by the War Office that a reduction of 20 per cent. in the number of troops carried should be made. On this proposal Brigadier-General Anderson reported that, failing a complete rearrangement of "overheading" between decks, it would be impossible to distribute this concession uniformly throughout the sleeping accommodation. He suggested that the existing Admiralty scale should be retained on all upper sleeping decks and that scale B should be applied to all the lower sleeping decks. The total average reduction in carrying capacity would then be found to be within the 20 per cent. reduction.

During the war Treasury sanction could not be obtained to this general reduction of 20 per cent., although during the recrudescence of influenza a reduction was permitted by the shipping authorities and during the repatriation of Dominion troops every soldier was allowed a hammock, which in fact did result in a diminution of accommodation by 20 per cent.

The Provision of Spray Rooms on Board Ship.

The shipping authorities informed the War Office conference that all ships conveying Australian or New Zealand troops had been fitted with spray rooms operated by the ship's steam. In certain ships fitted with spray rooms in Australia and New Zealand a portable steam apparatus of the Levick type was used. Orders had been given to fit spray rooms into all transports employed on North Atlantic routes. As a general rule one spray chamber had been fitted to each ship; each chamber measured 18 ft. by 10 ft. and had four steam jets of

the Hine pattern. Certain ships which carried about 6,000 men could be fitted with two or three chambers measuring 18 ft. by 10 ft., and probably four such chambers could be placed on the "Olympic."

The conference considered the circumstances in which steam spray disinfecting rooms should be used, and came to the conclusion that it was not a sound principle to send into the spray room for treatment, along with others, men who were suffering from acute affections, that acute catarrhal cases should be treated by hand sprays, and that contacts of measles, mumps, cerebro-spinal fever, and "carriers" should be treated in the spray room. In order to avoid the spread of infection by men coughing and sneezing it was considered most important that not too many men should be in the room at one time and that each man should have a floor space of approximately 27 sq. ft. A fresh current of steam and air should be kept passing through the spray room while the men were undergoing treatment, and after one batch of men had been treated the room should be thoroughly flushed with air before a second batch was introduced. It was recognized that it would take a long time to pass a large number of men through the spray room. In the ordinary room, 18 ft. by 10 ft., only six men could be introduced at one time, and allowing ten minutes for treatment and five minutes for the blow through of the chamber, only 576 men could be passed through the room in one day, even supposing it were possible to keep the spray working continuously for twenty-four hours. If it were not possible to pass the whole of the troops on board ship through the spray room, in the event of disease appearing in one compartment of the ship these men should be treated and kept apart from the other men as far as possible. Possibly two or three *foci* of infection could be dealt with in this manner, but if any further extension occurred the treatment would have to be limited to the the immediate contacts of the cases. In certain outbreaks, however, it would only be possible to protect by the steam spray treatment the actual staff in attendance on the sick.

Precautions taken to prevent the Introduction of Infectious Disease into the United Kingdom.

The general principles were to remove all cases of actual disease into special hospitals and to detain under observation direct and immediate contacts for the usual period of incubation

of the disease in question. When provision could not be made for the detention of contacts, these men travelled in separate carriages. The D.D.M.S. of the command and the medical officer of the camp were notified by telegram of the departure of the troops and the nature of the suspected infectious disease. The great difficulty on board ship was the question of contacts. Direct contacts were usually considered to be the men in hammocks immediately adjacent to the case and the men sitting close to him at the mess table. But in view of the intimate contact of all troops on the same deck, it was extremely difficult, especially in the case of influenza, to lay down any hard and fast rule as to which men should be detained as contacts. Moreover, when the period of demobilization arrived the risk of spreading influenza from contacts on board ship became very great, as the men went to their homes within twenty-four or forty-eight hours of their arrival in the United Kingdom. It was arranged that a special medical examination should be made of all the troops on board before the ship arrived in port, and if there had been no fresh cases of influenza for forty-eight hours, the sick were removed to hospital and, after nominal rolls had been prepared giving the name and destination of each man, the troops were allowed to proceed by train. The nominal rolls were sent to the Local Government Board for despatch to the medical officers of health of the districts to which the demobilized men were proceeding. If there had been any fresh cases within twenty-four hours, the whole of the troops, after the sick had been removed to hospital, were detained at camps adjacent to the ports, where they were kept under strict medical supervision for forty-eight hours. All healthy men were then allowed to proceed to dispersal camps or commands.

In the case of transports disembarking troops at Marseilles, if cases of influenza had occurred on the ship, all the troops were detained in a special camp for forty-eight hours. Healthy men at the end of that time were allowed to proceed by train across France to the Channel ports.

In the case of troops arriving for demobilization on ships also carrying civilians, special difficulties were experienced in dealing with contacts owing to the port medical officer allowing the civilians to proceed to their destinations. Men for demobilization who were not actually ill resented differential treatment, and the detention of soldier contacts in these circumstances was abandoned after the question had been referred to the Minister of Health, who decided that the port

medical officer had no power to detain civilians not actually suffering from influenza.

In the case of ships on which there had been a case of typhus fever or plague, arrangements were made, in addition to the usual precautions, to disinfect thoroughly all the troops at the port of disembarkation, before they were despatched by train to camps or dispersal stations.

APPENDICES

APPENDIX A.

SCHOOLS OF SANITATION, COURSES OF INSTRUCTION, ESTABLISHMENTS AND EQUIPMENT.

1.—*Courses of Lectures in the School of Hygiene, Blackpool.*
(*a*) *Officers' Course.*

Lecture I.—Introductory.—History. Organization and aims. Statistics. Investigation of questions of wastage of man power. Ætiology of disease.

Lectures II and III.—Physical Conditions.—Cold, trench feet, frostbite, etc.; heatstroke and the factors affecting heat production and dissipation. Clothing and equipment. Footwear and foot conditions. The march—water requirements and energy expenditure. General question of energy output in relation to speed, load, etc., and in connection with military problems. Indirect calorimetry. *Practical.*—Fabrics. Physiological methods, etc.

Lectures IV and V.—Dietetic.—The elements of a balanced ration—how estimated and constructed. Modern methods of assessing energy requirements. Cooking. Service and its amenities. Faulty foodstuffs. Various food poisons—metallic, bacterial, parasitic, fungoid, anaphylactic. Meat inspection, etc. Adulterated foods, preservatives, the vitamine question. *Practical.*—Starches, adulterants, preservatives, etc.—detection and recognition. Analysis of milk and its sophistication, butter, beer, etc. Demonstration of food-poisoning, etc. Detection of arsenic. Abattoir visit.

Lecture VI.—General Questions affecting all the Parasitic Invasions.—Immunity in theory and practice. Vaccines and sera. Diagnostic methods. *Practical.*—Detection of various pathogenic bacteria, inductive diagnosis, agglutination methods (also in theory, complement fixation, Schick test).

Lectures VII and VIII.—Notification.—The modes of recording, isolation and quarantine. *Disinfection.*—Physical and chemical methods, apparatus and technique. *Practical.*—Working models of majority of military appliances. The Rideal-Walker test for carbolic coefficients. Recognition of common disinfectants.

Lecture IX.—Contact Infections.—Scabies. The venereal diseases question in civil and military life. *Practical.*—Isolation and recognition of the responsible causes.

Lecture X.—Droplet Infections.—Their prevention, spacing out, hygrometry, etc. Ventilation in theory and practice. *Practical.*—Estimation of CO_2 in air, use of meteorological apparatus, etc.

Lectures XI, XII and XIII.—Excremental Infections.—Carriers, path of infection and barriers. Conservancy in the field and in barracks. Destructors. Sewage disposal. Water—sources, supply, collection, analysis and treatment. *Practical.*—Analysis of water—chemical and bacteriological. Estimation of " bleach " required and of its Cl content. Working of modern water plant using Cl gas and Wallace-Tiernan regulator. Cookhouse. Sewage works—siting, construction, appliances, etc.

Lecture XIV.—Flies.—Life-history, methods of prevention and destruction; varieties. *Practical.*—Recognition and classification of important genera.

Lecture XV.—Blood Infections.—(Majority dealt with in the Tropical Medicine lectures except lice-borne diseases.) Lice—life-history, character of commoner types, etc.; mode of prevention and destruction—insecticides, hot-air huts, laundries and bath-houses. *Practical.*—Recognition of important genera, mode of cultivation, etc. Practical work on sullage.

Lecture XVI.—Marine Hygiene, Maternity and Child Welfare.

Tropical Hygiene.

Lecture I.—Blood-sucking Insects.—Mosquitoes—general sketch of anatomy and development, classification, breeding habits, etc. Anti-mosquito measures. *Practical 1 and 2.*—Detailed study of anatomy of adult mosquitoes, larvæ, etc. *Practical 3.*—Identification of important species of Anophelinæ, Culicinæ. Use of keys. *Practical 4.*—Identification of important species, larvæ and adults.

Lectures II and III.—Malarial parasites and their effects. *Practical 5, 6, 7.*—Staining and recognition of foregoing.

Lecture IV.—Fleas.—Anatomy and life-history; plague; rats. *Practical 8, 9.*—Recognition of ova, larvæ, etc. Identification of a dozen of the more important genera and species.

Lecture V.—Psychodidæ; Simuliidæ; Chironomidæ; Glossinæ. *Practical 10.*—Identification of above. Demonstration of trypanosomes.

Lecture VI.—Bugs and ticks—classification, anatomy, life-history, etc. *Practical 11.*—Identification of a dozen genera and species. Demonstration of Spirochætes, Leishmania, etc.

Lecture VII.—Bacillary Dysentery.—Organisms concerned, methods of spread, carriers, etc.

Lecture VIII.—Amœbic Dysentery.—Classification and description of Amœbæ living in man; cysts, etc.; carriers, etc. *Practical 12 and 13.*—Identification of fresh or stained specimens of Entamœbæ, Endolimax, Iodamœbæ, cysts, etc.

Lecture IX.—Cholera.—Methods of spread, carriers, etc. Demonstration of Army cholera outfit.

Lectures X and XI.—Important Nemathelminths and Platyhelminths infecting man. *Practical 14, 15, 16, 17.*—Recognition of above. Identification of ova.

Lecture XII.—Revision, amplification of any points desired, demonstration of methods of preserving and mounting specimens, etc.

(*b*) *Men's Course.*

Lecture I.—Aims of hygiene; germs; protectionary reaction of body and explanation of immunity; vaccines and sera. *Practical.*—Demonstration of various micro-organisms, blood cells, phagocytosis, etc.

Lecture II.—Origins of Infection.—Varieties of carriers and how they spread disease; different groups of diseases so distinguished. *Practical.*—Bricks, laying, cutting, etc.

Lecture III.—Environmental Factors causing Disease.—Personal hygiene, heat, cold and exposure; clothing and equipment. *Practical.*—Brickwork (continued)—cements, mortars, etc.

Lecture IV.—Camp Sites.—Preparation—levelling, turfing, draining, trenching, siting, etc. *Practical.*—Foundations, bonding, arches, etc.

Lecture V.—Food.—Values, quality, inspection, etc. *Practical.*—Brickwork—constructional; use of plans, laying of drains, setting of manholes, etc.

Lecture VI.—Isolation and Quarantine.—Treatment of contacts; steam disinfection in theory and practice. *Practical.*—Working of steam disinfecting apparatus (box, barrel, Thresh, Foden-Thresh).

Lecture VII.—Disinfection.—Chemical methods; elementary mensuration. *Practical.*—Working of apparatus for chemical disinfection (McKenzie, Levick).

Lecture VIII.—Contact Infections.—Venereal diseases, scabies, etc.—causes and methods of prevention. *Practical.*—Demonstration of responsible causes. Treatment of sullage water from baths.

Lecture IX.—Droplet Infections.—Examples and relation to spacing out of men; ventilation, theory and apparatus. *Practical.*—Woodwork: use of tools, cutting, fitting, etc.

Lecture X.—Excremental Infections.—Further explanation on carriers. Conservancy—latrines. *Practical.*—Woodwork (continued)—making of latrine seats, box-safes, etc.

Lecture XI.—Conservancy.—Disposal of excreta and of waste matter in general, incinerators and destructors. *Practical.*—Construction and working of destructors.

Lecture XII.—Water.—Sources; examination of wells, etc.; selection; collection and delivery; importance. *Practical.*—Demonstration of micro-organisms, protozoa, eggs, etc., found in waters; improvement of wells; the water lorry (general).

Lecture XIII.—Water (continued).—Examination of quality by water sterilizing test case; interpretation of the test and application to "bleach" methods of treatment in water-cart, tanks, pakhals, etc. *Practical.*—Use of water sterilization test case; the water-cart.

Lecture XIV.—Kitchens and Associated Conveniences.—Siting, etc.; food stores, grease traps, swill tubs, etc. *Practical.*—Metal work, use of tools, cutting, shaping, rivetting and soldering.

Lecture XV.—Flies.—Importance: modes of spreading disease; important genera and their description. *Practical.*—Recognition of more important genera and of mode of development of flies.

Lecture XVI.—Anti-fly Measures.—Trapping, spraying, etc.; disposal of manure. *Practical.*—Metal work: improvisation of basins, doors, etc. from available material.

Lecture XVII.—Insect-borne Diseases.—Carrier insects—mosquitoes, lice, flies, bugs; description of dangerous types and how to distinguish them from harmless but similar forms; diseases conveyed; method of prevention by attacking insects—fumigation, drainage, anti-rat measures, etc. *Practical.*—Recognition of important genera.

Lecture XVIII.—Lice-borne Diseases.—Description; methods of disinfestation—laundries and baths, hot-air huts, insecticides, etc. *Practical.*—Metal and other constructional work.

Lecture XIX.—Sanitary Duties.—Orderlies in camps and barracks; sanitary sections on service; inspectoral work in camps and barracks. *Practical.*—Constructional work on models, using all tools as required.

Lecture XX.—Camp Inspection.—Revision of doubtful points. *Practical.*—Constructional work, actual models.

Half a dozen lectures and certain practical classes were taken by the officer instructors, the remainder by N.C.O. instructors. The course lasted at first for four weeks, or a total of 20 lectures, and later for eight weeks. Practical work varied according to weather and local constructional requirements.

2.—*Syllabus of a Course of Hygiene and Sanitation given to Medical Officers in Macedonia.*

(*a*) *At the Base.*

Sunday.

Class assembles and reports to officer commanding No. 1 Convalescent Depôt for accommodation and rations.

Monday.

9.0 a.m. to 12.0 noon at No. 1 Convalescent Depôt.—General principles of drainage of malarial districts.

Demonstration of Anopheles, varieties, larvæ, pupæ, etc.

2.0 p.m. to 5.0 p.m. at No. 1 Convalescent Depôt.—Types of field kitchen, incinerators, urinals, latrines, including use of cresol and heavy oils.

Tuesday.

9.0 *a.m. to* 12.0 *noon at No.* 1 *Convalescent Depôt.*—Food storage, cook-houses, washing up, disposal of ablution water, cook-house water, etc. Flies. Disposal of manure.

2.0 *p.m. to* 5.0 *p.m. at No.* 1 *Convalescent Depôt.*—Lice and lice prevention. Sanitary section, bathing and disinfection station. Lembet baths. Sulphur baths. (Scabies 20th Stationary Hospital).

Wednesday.

9.0 *a.m. to* 12.0 *noon at No.* 1 *Convalescent Depôt.* — Water sources and supplies in Greece, including demonstration of aqueducts, *e.g.*, Eurendjik aqueduct adjoining.

2.30 *p.m. at Summerhill.*—Demonstration of various types of field septic tank and contact beds. (Conveyances will be provided and will leave No. 1 Convalescent Depôt at 2.0 p.m.)

Thursday.

9.0 *a.m. to* 10.15 *a.m. at Base Laboratory.*—Bacteriology and chemistry, including chlorination with practical demonstration—water sterilizing test case, metallic poisons, etc.

10.30 *a.m. to* 12.0 *noon at No.* 52 *General Hospital.*—Bacteriology of dysentery—amœbic, etc.

2.30 *p.m. at Monastir Road, No.* 15 *Veterinary Hospital.*—Demonstration of disposal of manure. Large scale.

Friday.

Class disperses.

(*b*) *In the Field.*

First day :—

09.00 to 09.30	Introductory lecture.
09.45 to 12.00	Practical work—building of hillside latrine.
14.00 to 14.30	Lecture on flies and disposal of excreta.
14.45 to 16.00	Practical work—building incinerator and grease pit.

Second day :—

09.00 to 09.30	Lecture—malaria and its prevention.
09.45 to 12.00	Practical work—urine pit and sullage pit.
14.00 to 14.30	Lecture—camp sanitation.
14.45 to 16.00	Practical work—manure incinerator.

Third day :—

09.00 to 09.30	Lecture—dysentery and typhoid.
09.45 to 12.00	Practical work—disinfection of clothes.
14.00 to 14.30	Lecture—body cleanliness.
14.45 to 16.00	Clearing up camp.

3.—*Syllabus and Personnel for a School of Sanitation in an Army in France.*

Syllabus.

1. *Course A.*—For pioneers, carpenters, metal workers, bricklayers and handymen. Practical instruction in the making and erection of permanent and semi-permanent sanitary appliances. Duration of course—5 days. Number of students—30. Course to be divided into three distinct sections, so that all students will have training in carpentry, metal work, bricklaying, and out-door constructional work.

2.* *Course B.*—For the sanitary personnel of units. Instruction to consist of elementary lectures in sanitation, demonstrations in camp sanitation,

* Classes for Officers to be substituted for Course B when desired.

and practical instruction in the temporary sanitary measures to be employed in the field, as distinct from permanent and semi-permanent measures.

Duration of course—3 days. Two courses to be held weekly, with 25 students in each course. Total number of students—50.

3. *Course C.*—For men employed in water duties. Instruction to consist of lectures on the general principles of water supply, the chlorination of water and clarification of water. Special attention to be paid to practical demonstrations on the water-cart itself, in order to ensure that every man is familiar with the spare parts and fittings on the cart, and the methods to be employed in the maintenance of the cart and keeping these spares and fittings in good order.

Establishment.

(*a*) One officer. To be a medical officer with special qualifications in sanitary science ; to act as commandant ; to supervise and control the scope of the work, and to give introductory lectures to the students ; to interview visitors and advise on sanitary matters as they arise.

(*b*) One staff-sergeant. To supervise general discipline.

(*c*) Three sergeant-instructors for Course A.

(*d*) Two sergeant-instructors for Course B.

(*e*) One sergeant-instructor for Course C.

(*f*) One corporal—as clerk.

(*g*) Three privates—two to act as cooks and one for general duty, maintenance of tools, &c.

(*h*) One bâtman.

Six men would be required for general fatigue work, cleaning and disinfecting of billets and school premises, attending to baths, incinerators, disinfectors, latrines, etc., as a considerable number of working models would be continually in use for demonstration purposes.

The selection of the staff-sergeant and six sergeant-instructors should be made from men who have a thorough knowledge of sanitation, such as men who have been employed in civil life as sanitary inspectors to local authorities, or are known to be well advanced in sanitary matters.

4.—*Course of Instruction in a School of Sanitation in a Corps in France.*

1. *Subjects Taught.*—The Corps School of Sanitation will open at the Corps Rest Camp for instruction of officers and men in sanitation, first aid and chiropody.

2. *Duration of Course.*—Each course will last six days. Officers, N.C.Os. and men will be chosen from residents in the camp.

3. *School Staff.*—The staff will consist of :—The Commandant, who will be the Commandant of the Corps Rest Camp ; Assistant Commandant ; Instructors : two sergeants from sanitary sections ; Assistant Instructors : three corporals from a field ambulance.

4. *Number attending Courses.*—Sanitation, 50 ; first aid course, 50.

5. *Special Lectures.*—Special lectures will be arranged each week when possible. All students must attend these special lectures.

6. *Instruction in Sanitation.*—This consists of : (*a*) A course of lectures in accordance with attached syllabus ; (*b*) Practical classes in the manufacture of sanitary appliances ; (*c*) Instruction by means of models. A collection of models of sanitary appliances will be arranged.

7. *First Aid Course.*—The course will consist of a series of lectures and practical work. Special attention will be given to practical work. The pupils will work in couples, and practise bandaging, etc., on each other.

8. *Special Lectures on Chiropody.*—Special lectures and practical demonstrations will be given on chiropody and the care of the feet.

Syllabus.

Time.	*Subject.*
Monday.	
9.30 a.m.	General principles of preventing disease.
10.30 a.m.	Air and ventilation. Insects and diseases, with special reference to flies.
1.30 p.m.	Practical instruction in water testing.
2.30 p.m.	Water-carts, water-bottles and water-tanks. Their care and management.
3.30 p.m.	Practical demonstration on construction of urinals and latrines.
5. 0 p.m.	Personal cleanliness and physical culture.
Tuesday.	
9.30 a.m.	Food and food storage and the principles of cooking.
10.30 a.m.	Personal hygiene and the prevention of scabies and lice.
1.30 p.m. – 5. 0 p.m.	Practical demonstration on cookhouses, camp baths and latrines.
Wednesday.	
9. 0 a.m. – 12. 0 noon	Latrines, trench and urine pits.
1.30 p.m.	Infectious and contagious diseases.
2.45 p.m.	Practical work in the construction of improvised meat-safes and food stores.
Thursday.	
9.30 a.m.	Bivouacs, camps and billets.
10.30 a.m.	Disposal of excreta and refuse, and demonstrations of working of destructors.
2. 0 p.m. – 4. 0 p.m.	Water and water supplies, with practical demonstration of source of supplies.
Friday.	
9. 0 a.m. – 12. 0 noon	Camp construction and camp drainage.
2. 0 p.m.	Disinfectants, their use and abuse.
3. 0 p.m. – 5. 0 p.m.	Demonstration of various methods of disinfecting and disinfesting.
Saturday.	
9. 0 a.m.	Sanitary arrangements in trenches.
10.30 a.m.	Demonstration on trench latrines and urinals.
11.45 a.m.	Final Lecture.
2. 0 p.m.	Class dismissed.

Classes for constructional work will be held each evening from 7.0 to 8.0 p.m. by the sanitary instructors. This work will embrace the making of improvised meat-safes, stores for food, urine funnels, etc.

Samples and models of various contrivances used in camp sanitation will be exhibited and the working explained.

5.—*Mobilization Store Table for an Army School of Sanitation (France).*

Article.	*Number.*
Bags, ration, Mark II.	13
Bottles, water, enamelled	12
Tins, mess, dismounted services	12
Infantry equipment, pattern 1914 :—	
Attachments, brace	24
Belts, waist	12
Braces	24
Carriers, water-bottles	12
Haversacks	12
Packs	12
Straps, pack	24

Article.	*Number.*
War equipment, pattern 1908 :—	
Covers, mess tin	12
Axes, felling, curved helve	2
,, hand, Mark II.	2
Boxes, candle (filled), F.S.	6
Kettles, camp, oval, 12 qts.	8
Lanterns, tent, folding	6
Sheets, ground	12
Axes, pick (heads, 4½-lb.)	6
,, ,, (helves, 36-in.)	6
Spades, Mark III.	10
Axe, hand, 3-lb.	1
Bevels, carpenters', 9-in.	2
Bits, sets of 24	2
,, twist, sets	2
Braces, 10-in. sweep	2
Bradawls, assorted	12
Blades, saw, keyhole	12
Chisels, Firmer, ¼-in., ½-in., ¾-in., 1-in. each	4
,, hand, cold, ¾-in. by 8-in.	2
Chest, tool, carpenters', No. 4 (empty)	1
Compass, wing, G.S., 10-in.	1
Files, saw, hand, 6-in.	24
,, ,, ,, 3-in.	12
Gauges, marking, single	4
,, inside ground, ¾-in.	2
Grindstone and trough, 24-in.	1
Hammers, carpenters', 10-oz.	6
,, claw, 16-oz. (Canterbury No. 2)	2
Handles, file, saw	6
Mallets, carpenters'	2
Oilstones (" Washita "), 9-in.	2
Oilcans, small	2
Pencils, carpenters', blacklead, 7-in.	72
Pincers, carpenters', 8¼-in. prs.	4
Planes, jack, double iron, 2¼-in.	4
,, jointing, 2⅝-in., iron	1
,, smoothing, G.S., 2¼-in., double iron	2
,, rebate, 1¼-in. blade	1
Pliers, side-cutting, 7-in.	1
Punches, tinman's, small flat-nosed	6
Rules, G.S., four-fold, 2-ft.	6
Saws, hand, 26-in., G.S.	4
,, ripping, 28-in., coarse teeth	1
,, 14-in.	4
,, keyhole, 9-in. blade	1
Screwdrivers, G.S., 9-in.	3
,, G.S., 14-in.	1
Sets, saw, hand	1
Slips, oilstone, 4-in.	2
Spokestones, 3-in. blade	4
,, 2½-in. blade	2
Squares, try, carpenters', 9-in.	6
Blades, saw, hack	24
Chest, tools, empty	1
Chisels, hand, cold, ¾-in. by 9-in.	4
Drills, trench, 2 speeds	1
,, S.S., ⅜-in., ¼-in. each	6

Article.	*Number*
Files, half-round, 10-in.	6
Hammers, riveting, 12-oz.	4
,, ,, 16-oz.	1
,, G.S., 12 oz.	4
Handles, file	6
Irons, soldering, hatchet-shape	1
Lamp, petrol, brazing, 5 pints	1
Pliers, cutting, 7-in. prs.	2
,, flat-nose, 6-in. prs.	4
,, round-nose, 6-in. prs.	2
Punches, tinman's, small flat end	4
Rules, G.S., fourfold, 2-ft.	4
Saw, hack, 12-in.	1
Sets, riveting, $\frac{1}{8}$-in. prs.	2
,, seam, $\frac{1}{4}$-in. prs.	2
Snips, tinman's, pincer handles, 10-in. prs.	4
Vices, parallel jaws, instant grip, 45-lb.	1
Chisels, masons', 12-in. by $\frac{7}{8}$-in.	4
Chest, tools, bricklayers', No. 2, empty	1
Hammers, pick and hammer	6
Levels, spirit, Blick	3
Lines, bricklayers', 3-strand	5
Pins, line, iron, bricklayers', $5\frac{7}{8}$-in. prs.	3
Squares, masons', wood	1
Tapes, measuring, Cheeseman's, 83-ft.	1
Trowels, masons', 16-in.	6
Barrows, stable	2
Brooms, bass, head, common	8
,, ,, handles	8
Brushes, scrubbing	6
Clippers, hand	1
Implements, butchers':	
Balances, spring, 4-lb.	1
Cases, wood, empty	1
Choppers, meat	1
Hooks, dressing, 9-in.	6
Knives, cutting	2
,, flaying, large	1
Saws, tenon, 14-in.	1
Sheets, ground (unserviceable)	1
Steels	1
Steelyards, 56-lb.	1
Knives, opening tins	3
Pails, iron, galvanized, 4-gall.	8
Pots, watering, small	2
Blankets, S.S. (or G.S.)	12
Cartridges, small army ball pistol, Webley	36
Frocks, dungaree	15
Trousers, dungaree, prs.	15
Brassards	13
Dressings, field	13
Disinfector, portable, box pattern	1
,, spray	2
Cases, water-testing (Horrocks')	2
,, ,, (chemical)	1
Blackboards, large	1
Chalk, boxes, assorted	1
Dusters	2

APPENDIX B.

WATER PURIFICATION.

1.—*Equipment of Standard Water Sterilization Test Case.*

(*a*) *Cups.*—One to hold 250 c.c. when filled to within ½ in. of the brim, enamelled blue inside, and to be used for making up the strong chloride of lime solution. Six conical cups, enamelled white inside, to be filled within a ½ in. of the brim with the water to be tested.

(*b*) *Spoons.*—Three teaspoons, each holding 2 grammes when filled level with the brim with bleaching powder.

(*c*) *Can.**—A large bicycle oil can fitted with a screw cup and well turned. This contained the test solution.

(*d*) *Pipettes.*—Four pipettes of glass tubing of 2·6-mm. bore and 6 in. in length.

(*e*) *Handkerchief.*—A handkerchief of thin material, one fold placed over the finger covering the end of the pipette, enabled uniform drops to be delivered.

(*f*) *Test Solution Reserve.*—A two- or three-ounce bottle, tightly stoppered with glass stopper, contained the solution.

(*g*) *Stirrers.*—Six glass rods, each about 6 in. long.

The above articles were fitted into a box provided with suitable partitions. The sides of the box were hinged so that they could be let down and then gave sufficient room for the cups to be placed on them for testing purposes. The following instructions in the use of this test case were given :—

(1) The six cups are to be arranged in a row, and each is then filled to within ½ in. of the brim with the water to be tested.

(2) Two grammes of bleaching powder, *i.e.*, one spoonful with the powder just level with the brim, are made into a paste with water in the blue enamelled cup, then filled to within ½ in. of the brim with water which is to be tested.

(3) To the six test cups are added one, two, three, four, five and six drops respectively of the concentrated bleaching powder solution in the blue cup, and to each of the test cups are then added three drops of the test solution of zinc iodide and starch and the contents of the cups are vigorously stirred. (Later the test solution was not added until after an interval of half an hour.)

(4) Some of the cups of the series will usually give a definite colour which is not discharged by stirring, and remains permanent for half an hour. Then for every drop of strong bleaching powder added to the cup, which just gives a blue colour, one tin measure of the bleaching powder should be made into a paste and thrown into the body of the cart and well mixed with the water; where the body of the cart is divided into sections, an aliquot part will be added to each section. For instance, suppose cups one and two became colourless, but the third cup showed a distinct blue colour, then three teaspoonfuls of bleaching powder would be added to the cart. If the colour disappears from all the cups, then the test must be repeated and seven, eight, nine, ten, eleven and twelve drops respectively of the concentrated bleaching powder added to the test cups. This was rarely necessary.

(5) As a control, the water in the cart should be tested at intervals to see that a blue colour is given with the test solution. If a blue colour is maintained for half an hour, then the water in the cart will be safe for drinking.

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* Later this can was replaced by glass dropping-bottles.

2.—*Suggestions for the Efficient Working of Filtration Units.*

The process of water purification for which the filtration units are adapted consists of four operations :—

(1) Coagulation of the suspended matter with alum.
(2) Filtration through sand.
(3) Sterilization with chlorine gas or chloride of lime.
(4) Dechlorination with either sulphur dioxide or sodium sulphite.

Coagulation with Alum. The material supplied is a crude sulphate of aluminium, and this should always be requisitioned in preference to alum.

A preliminary examination of the water to find out the degree of alkalinity or acidity should be made, using lacmoid as indicator (methyl orange may be used, but it is not very sensitive, and does not react with dissolved carbon dioxide), the titrations being carried out with N/50 sulphuric acid or N/50 sodium carbonate respectively.

If the water is alkaline, then the number of cubic centimetres of acid required to neutralize 70 c.c. of water gives the alkalinity in grains per gallon (calculated as $Ca\ CO_3$).

Similarly the acidity of the water is obtained from the sodium carbonate titration.

It should be noted that alkalinity is not the same as hardness, as the latter might be due to the presence of chlorides of calcium and magnesium, which would have no effect on the alkalinity.

Each grain of aluminium sulphate, $Al_2(SO_4)_3 18H_2O$, requires one-half grain of natural alkalinity, as determined above, for complete precipitation.

If the water is deficient in alkalinity, or is acid (as found in certain districts), soda ash must be added in a definite quantity, depending on the deficiency and the amount of alum used.

In the alum or alum and soda pre-treatment, full advantage should be taken of all facilities for settling ; thus if two chambers are provided (as in the barges), the coagulant should be added as the water enters the first chamber, and not between the two, or immediately before the filters, except in special cases.

It is also essential that the minimum amount of coagulent that will give the desired result should be used both for the sake of economy and for the efficient working of the filters.

Filtration through Sand.—The efficiency of a sand filter depends upon the formation of a skin, either natural or artificial, on the surface of the sand or, in the case of the drifting sand filter, among the drifting sand.

In pressure filters this skin is nearly always artificial, and consists of aluminium hydrate. As the thickness of the skin increases, the pressure rises. The pressure may be allowed to reach about 20 lb per square inch when it becomes necessary to reverse the flow and wash out the filter.

It is therefore advisable to form the skin as quickly as possible after back-washing the filter, and to keep it as thin as possible during working, that is, to use a minimum quantity of alum necessary for clarification. If the raw water is of very good quality it is sometimes sufficient to form a skin on the filter, and then cut off the supply of coagulant until the sand needs washing and the filter reforming. This applies more especially to stationary bed filters.

Precautions should be taken to ensure that no air is left in the filter after washing, as this agitates the surface of the sand and prevents the formation of a regular layer of alumina-hydrate. Air-cocks are fitted on all filters, and these should remain open until a steady stream of water flows through each. No filter can be considered to be working efficiently unless 90-95 per cent. of the total organisms are removed by filtration alone, and with care even a higher percentage can be removed.

The efficient working of the filter should be maintained so that, in the event of the supply of chlorine failing and sterilization being impossible, a fairly pure water may still be supplied.

Under these circumstances the alum dose can be increased with advantage.

In the Ransome-Ver Mehr drifting sand filter a portion of the raw water is by-passed through the sand-washer and takes the washed sand up through the centre of the filter and distributes it on the top. The amount of water diverted from the main flow is controlled by a valve on the raw water inlet. The larger the volume of water sent through the sand washer, the greater will be the loss of head and the smaller will be the working margin of pressure available to overcome the increased friction of the filter when the sand ultimately begins to get clogged. Hence the minimum amount of water should be diverted which will keep the sand just moving down the extractors into the washer.

Sterilization.—This may be done with either chlorine gas or chloride of lime. The amount of reagent used depends upon the character of the water and can only be found by trial. The amount of chlorine absorbed is proportional to the amount put in, and is not a constant quantity, hence an estimation of the excess chlorine will not give indication of the efficiency of the treatment. This is illustrated by the following figures obtained from a test at Richmond with Thames water :—

Initial Chlorine.	*Excess Chlorine.*	*Chlorine absorbed.*
3·75	3·1	0·65
2·5	2·0	0·5
1·25	0·6	0·65
0·625	0·6	0·025

In one case the excess was the same when 0·625 parts per million were added and when 1·25 parts were added, and in the former case the water was not sterile.

A preliminary test on the following lines should be made to find the most suitable dose.

Five parts chlorine per million should be added, and, after about two hours' time, samples should be taken and 100 c.c. examined for *B. coli*. The initial chlorine should then be cut down by stages, 4 parts, 3, 2, 1½, 1 and ½, and 100 c.cs. of water examined corresponding to each dose, two hours being allowed to elapse between altering the chlorine dose and taking the 100 c.c. sample.

The results of the incubation will show the dose which just ensures sterility in 100 c.c. This should be noted, and half a part per million given in excess, *e.g.*, if the sample taken when 1½ parts per million were being used was not sterile, but that when 2 parts were used proved sterile, then a safe dose would be 2½ parts per million.

The results of this test are of little value if the filters are not working well at the time of the test, and if the standard of filtration is not maintained.

The quality of a large volume of water will not alter appreciably over a short space of time, but may change considerably with the seasons, so that a control test of the raw water should be made as well as of the effluent.

Chloride of lime may be used in cool climates, but is of little value in hot regions, and if it should have to be used as a stand-by in Mesopotamia, the kegs should be opened just when required and the available chlorine estimated before use.

The parts chlorine per million in water may be readily estimated by titrating 200 c.c. of the chlorinated water with N/180 thiosulphate, the number of cubic centimetres thiosulphate being the same as the parts chlorine per million in the sample.

Dechlorination.—This process may be carried out by either sulphur dioxide or sodium bisulphite, and should always be done if the water is for immediate consumption. If the water is stored for 24 hours, or even less, at warm temperatures, the excess chlorine will be absorbed and dechlorination will not be necessary. Also if the water has to be pumped any distance away from the unit, it is advisable to leave a small excess of chlorine.

In the latter case samples for bacteriological examination should always be taken at the point of delivery, and not only from the sterilizing tank.

The vapour pressure of sulphur dioxide at ordinary temperature is not sufficiently high to work against more than about 50 ft. of water, so the cylinders and pressure gauges are kept in an incubator at 90° F. This corresponds to a pressure of 60 lb.

The Wallace-Tiernan Chlorine Meter.—This instrument is very delicate, and is capable of giving a very accurate dose. The booklet of instructions issued by the makers should be followed in all cases and, in the event of a stoppage, the following points should be seen to :—

(1) That the chlorine cylinder is turned on and is not empty.
(2) That the valve on the diffuser is open.
(3) That the gas lines are not choked.

Note.—Some of the cylinders may have a tube fitted inside, so that they deliver liquid and not gaseous chlorine. In this case the cylinder should be inverted in the rack, which is arranged for that purpose.

Bacteriological Control.—The routine examination of the water should be on the following lines :—

(1) Total organisms per c.c. in the raw water capable of growing on nutrient agar at blood-heat.
(2) Do. in the filtered water.
(3) Do. in the sterilized water.

From (1) and (2) the percentage reduction of the organisms by the filter may be calculated.

(4) *Bacillus coli* per c.c. in the raw water.
(5) *B. coli* per c.c. in the filtered water.
(6) *B. coli* per 100 c.c. in the sterilized water.

In the sterilized water *B. coli* should be absent in 100 c.c. When examining the sterilized water 100 c.c. should be taken and divided equally among 10 tubes of double strength MacConkey broth (10 c.c. broth per tube).

This is very different from taking, say, 250 c.c. and removing 10 samples of 10 c.c. and rejecting the remaining 150 c.c.

It is also advisable to take 100 c.c. in 10 tubes and not in two (*i.e.*, of 50 c.c. each), for if two *B. coli* were present in 100 c.c., then in the former case two tubes would react, whereas in the latter case, if both 50 c.c. tubes showed acid and gas, no definite information could be gathered as to the number of organisms per 100 c.c. (*i.e.*, there would be two or more per 100 c.c.).

The following text-books are supplied with each unit :—

(1) " The Examination of Water and Water Supplies," by C. Thresh.
(2) " Quantitative Analysis," by Clowes & Coleman.
(3) " Handbook of Practical Hygiene," by Beveridge & Wanhill.
(4) " A Manual of Bacteriology," by Hewlett.

3.—*Working Instructions for a Chlorine Gas Type of Water Sterilization Plant.*

(i). *Testing Water to be Purified.*

Immediately the source from which the water is to be drawn for purification is decided upon, the man in charge of the sterilizer will carry out a test to determine the quantity of chlorine to be added to sterilize the water. This test will be carried out by means of the water sterilization testing case. Complete instructions will be found on p. 367. They are also included in each case.

He should put up the test as quickly as possible, so that by the time that the sterilizer is ready to filter water he knows from this test the actual amount of chlorine to add by means of the Wallace-Tiernan chlorinator. The test is complete in half an hour, and this gives ample time to have the sterilizer ready to filter water.

(ii). *Before Starting Plant.*

(1) Jack up the lorry.
(2) Examine all hose connections, which must be air-tight. Also see that the strainer is properly fitted to the suction hose.
(3) Partly fill the pump priming funnel with water, and have a bucket of water ready for priming. Priming, if necessary, will be done by adding water slowly through the funnel and opening valve (PV).
(4) *Close* drain-valves from :—

Chlorine diffuser cylinder (CDD) ;
SO_2 diffuser cylinder (DDD) ;
Funnel below sand-filter air-release pipe (A1) ;
Funnel below engine circulation overflow (A3) ;
Laboratory sink (A2) ;
Contact tank (CT) ;
Alum tank, both outlets (AD) and (AV).

(5) Open the following valves :—

Bypass on pump (BP) ;
Contact tank inlet valve (CWV) ;
Valve (ACT) on alum tank filling pipe (this also acts as air-release for contact tank) ;
Effluent valve (D1) or (D2).

(6) Whether or not alum is to be added subsequently, put sufficient water in alum tank to cover both outlets.

(iii). *On Starting up the Plant.*

Open the following valves :—

Valve (AV1) on sand filter air release pipe. (This must be kept open until operation IV is carried out.)

Sand filter valves (SF4) and (SF2).

Close

Sand filter valves (SF1), (SF3) and (SF5).

(iv). *Starting the Engine.*

When the above operations have been carried out, the engine can be started.

Close the pump bypass (BP) gradually until suction begins, and then close it completely and watch the stream of water from the drain. As soon as this is clear, or as clear as the source of water, proceed to carry out operation (v).

Operation (iv) is for the purpose of filling the sand filter from the bottom, so that all air is displaced by water, thus leaving the whole of the sand as one unbroken bed. It is not necessary to continue this operation any longer than just explained. In fact, when the sand filter is clean, it is only carried out in order that all the air may be removed from the filter and replaced by water. If, however, the filter has been used for some time, this operation backflushes the sand, *i.e.*, the water passing up through the sand causes the material which has been filtered out during previous use to pass away with the backflush water as it leaves the top of the filter.

One of the men must see that the valves (CW1) and (CW2) are closed when starting, and afterwards control the cooling water for the engine by means of these valves. The engine runs best if fairly warm. If valve (CW1) is shut and valve (CW2) used to control the flow of water, then, after cooling the engine, it will pass to drain (A3), but if (CW2) is shut and (CW1) used, then the water will return to the suction pipe of the pump, thus preventing wastage.

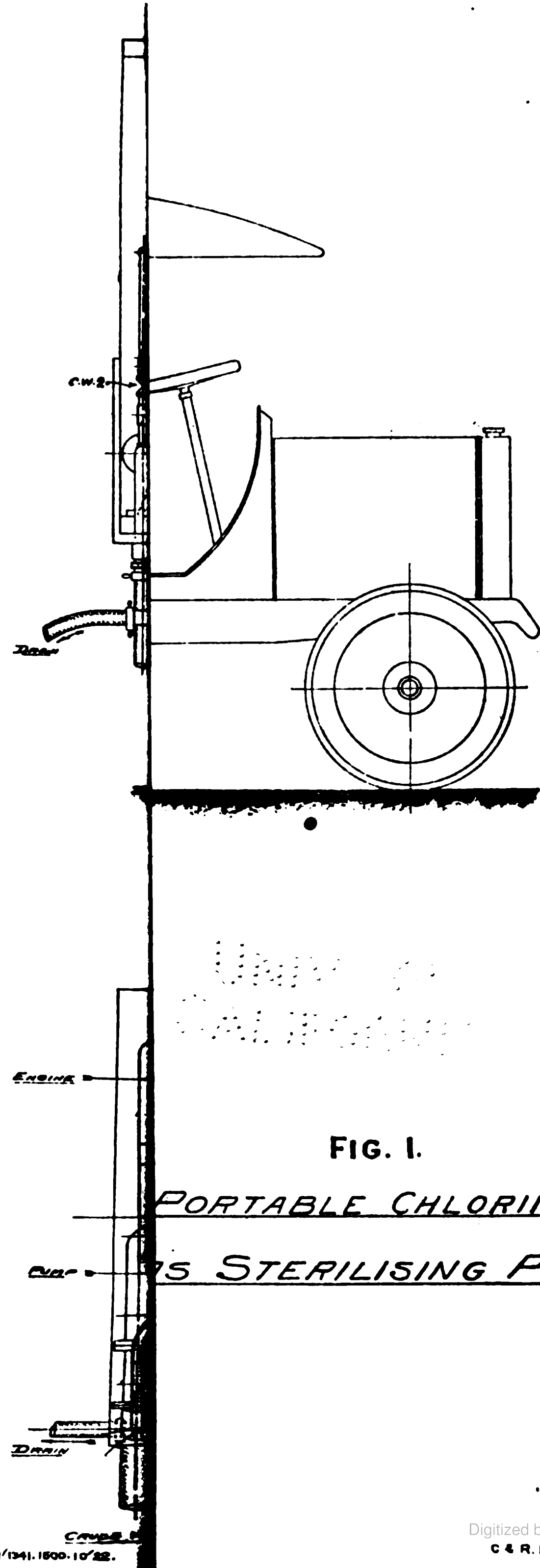

FIG. I.

PORTABLE CHLORINE
STERILISING PLANT

(v). *Changing to Filter.*

After these four operations have been carried out.*

Open the bypass (BP) a turn or so to reduce flow. With the bypass closed 2,000 gallons an hour are pumped.

Open sand filter valve (SF1) and *close* (SF4).

Open the drain valve (AL1) from the funnel below sand filter air release pipe.

Open sand filter valve (SF1) and *close* (SF4).

Open sand filter valve (SF2), keeping (SF3) *closed.*

Close sand filter valve (SF5) until water just flows from sand filter air release pipe.

Do not close (SF5) too much or the gauge on sand filter air release pipe will register a high pressure. Open (SF5) if this happens.

By this operation all air is removed from the sand filter and the unfiltered water at the bottom of the sand filter will pass to the drain. By this time the quantity of chlorine to be added will be known from the result of operation I.

Open drain valve (A2) below laboratory sink.

Open main tap on chlorine cylinder.

If it has been decided that alum must be added in order to filter the water perfectly, the necessary solution should have been made up and put into the alum tank. The entrance of this solution to the water is regulated by means of the valve (AV). A film of aluminium hydroxide is deposited on the surface of the sand, thus filtration is facilitated.

Everything is now ready to carry out the following operations :—

(1) Sending filtered water into the machine.

(2) Adding chlorine to this filtered water.

The second of these operations should be carried out as quickly as possible after the first has been performed, in order that the water passing into the contact tank may be chlorinated.

(vi). *Passing Filtered Water into Plant.*

Open valve (SF3) and *close* (SF5). Valve (SF3) should be slightly closed so that a little water escapes from sand filter air release pipe and the pressure recorded by the gauge still remains low, about 4 to 6 lb. Water now passes through the meter into the chlorinating cylinder, the air release tap of which should be left open until water escapes from it. From time to time it is opened to allow the escape of any air that may have collected in the cylinder.

(vii). *Instructions for Manipulating the Wallace-Tiernan Chlorinator.*

To Start the Apparatus.—Make certain that the valve on the check valve of the diffuser is open, otherwise the back pressure will rise above the working back pressure of the check valve, namely, 25 lb., which will cause the manometer liquid to be blown out of the tube when the valve is opened. Make certain that the blow-off valve (K), the control valve (E) and the auxiliary tank valve (B) are closed. Open the valve (A) on the cylinder head ; one turn is sufficient. Open the auxiliary tank valve (B). The tank gauge will rise slowly until the maximum pressure is reached. This will be between 50 and 75 lb., according to temperature. Open very slowly the control valve (E). The liquid will rise in the manometer tube and at the same time the pressure recorded on the back pressure gauge will slowly rise until a pressure of 25 lb. is obtained. The control valve should now be adjusted until the required number of pounds per hour of chlorine passing through the instrument is registered by the manometer liquid on the manometer scale.

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* Sand filter valves (SF3) and (SF4) must never be opened together. No unfiltered water must pass through the meter or the latter will become blocked, causing high pressure to be registered on the gauge and a stress thrown on the engine and pump.

To Shut Down.—Close the auxiliary tank valve (B). The tank pressure will fall to 25 lb. It is not necessary to close the valve on the cylinder head or the valve on the check valve during any temporary stoppages at night or otherwise.

To Empty the Apparatus of Chlorine E.—This is necessary only when the apparatus is to be disconnected for any purpose, or if the plant is not going to be used for some period.

See that the auxiliary tank valve (B) is closed and that both back pressure and tank pressure gauges are showing the same readings. This will necessarily be the case if the auxiliary tank valve is closed first and the chlorine allowed to pass through the diffuser in the ordinary way. When this is the case remove the plug on the air release pipe and open very slowly the valve (K), watching all the time the manometer liquid and checking the rate of flow of chlorine as necessary.

Note.—Never leave any part of the apparatus so that moist air can enter, as otherwise corrosion takes place. Before starting see that the auxiliary valve fitted to the check valve (M) is open, and that it is shut when work is finished. "Gate valves" are not fitted to mobile water sterilization plants.

Always test for leaks with the ammonia bottle provided, and replace washers at joints if necessary. Never screw down control valve hard or it will be damaged. Note that all valves are differentially threaded, and consequently allowances must be made for "backlash." The utmost care must be taken in using the control valve and in emptying the instrument, as otherwise the manometer liquid will be driven out of the tube and it may get into the compensator. It is necessary to keep the tank pressure at not less than 45 lb. in cold weather. In order to do this the paraffin stove must be kept burning in the cupboard to warm the cylinder. If this is not done, chlorine will in all probability liquefy in the instrument. It is important that the instrument should not be allowed to get colder than the cylinder, otherwise liquefaction of the chlorine in it will take place.

(viii). *Filling the Contact Tank.*

Keep air release pipe valve (ACT) open; this air release pipe is used to fill alum tank as required. When water flows from it, close valve (ACT). While contact tank is filling check rate of flow by the meter and adjust flow if necessary by the pump bypass (BP) until 1,200 gallons per hour are recorded.

Note.—Closing the bypass (BP) increases the water passing through the machine.

(ix). *Starting and Adjusting* SO_2 *Dechlorinating Apparatus.*

When valve (ACT) is closed as directed in the above operation, water which has passed through the contact tank will begin to fill the SO_2 diffuser cylinder, and SO_2 will have to be added to remove the excess chlorine. The apparatus to do this consists of a cylinder of liquid SO_2 and a Brin's fine adjustment valve (B), auxiliary valve (A), gauge (C), and a non-return valve or check valve. From (A) a tube leads to the diffuser on the dechlorinatiing cylinder. A non-return valve or check valve (D) is fitted to the top of the diffuser in order to prevent water getting back into the SO_2 supply pipe.

If SO_2 is now passed through the valve and then shut off, a pressure will be recorded on the gauge. This is the back pressure caused by the valve (D), and no SO_2 will pass into the water until this is exceeded.

The back pressure can be adjusted by altering the position of the rubber tube on the glass tube in the non-return valve or by resetting the check valve spring.

To dechlorinate:—

(1) See that the Brin's valve (B) and the auxiliary valve (A) are closed. If a valve is fitted next to the non-return, open it.

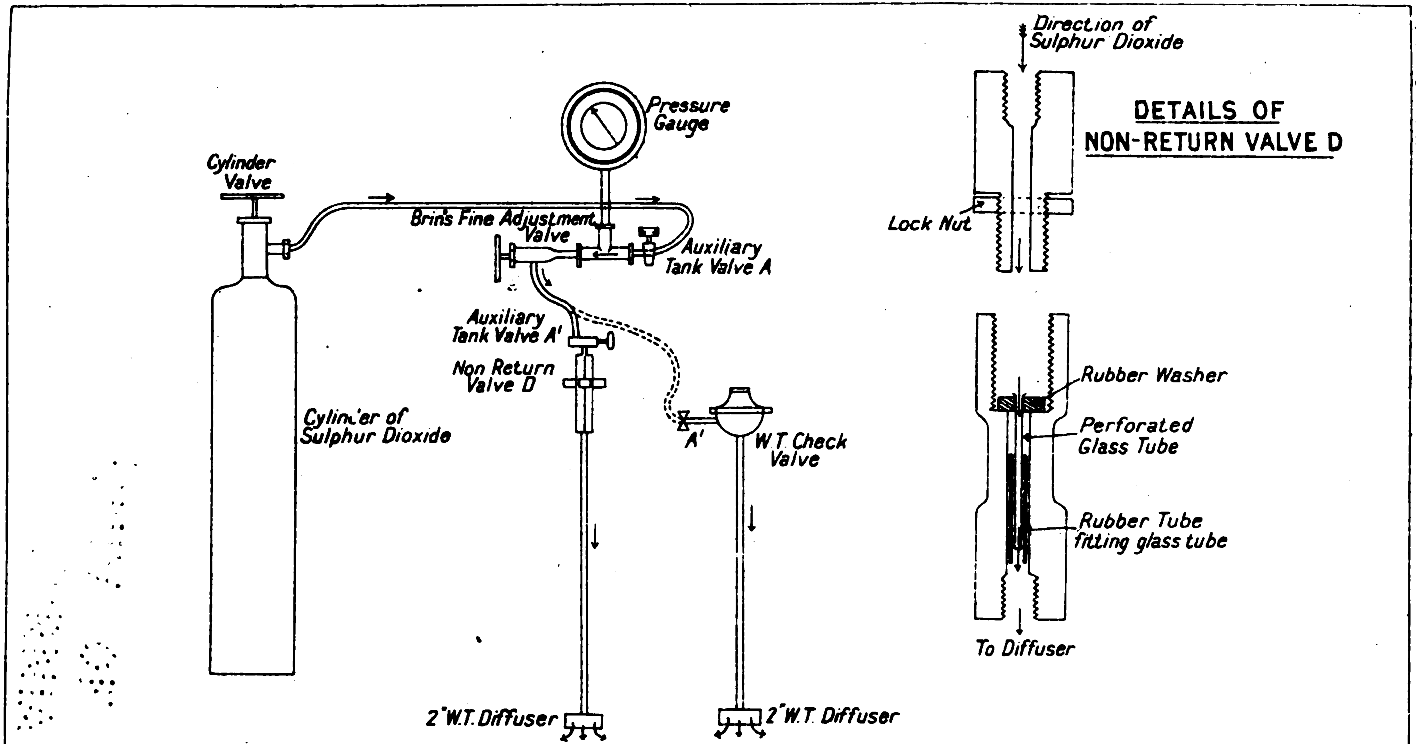

FIG. 2.

DECHLORINATION APPARATUS USED ON MOBILE STERILIZERS.

Malby & Sons. Lith.

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2. Open the valve on the SO_2 cylinder and auxiliary valve (A), and then slowly open the Brin's valve. The gauge will indicate a pressure. As soon as this pressure is the slightest in excess of the known non-return or check-valve pressure, an estimation of the chlorine content of the water must be made. The method of determining the quantity of SO_2 to add is carried out as follows :—A solution of sodium thiosulphate, 5·38 grams per litre, is made. Into a bottle is put 250 c.c. of the water to be tested, obtained from the sample line in laboratory and measured by means of the black cup in the water sterilization testing case, which just holds 250 c.c. when filled to the mark, and a little potassium iodide and starch solution added. By means of one of the pipettes from the same case drops of the sodium thiosulphate solution are added until the blue colour just disappears. Each drop so added corresponds to 0·2 part of chlorine per million of water. If the chlorine is in excess of the amount that is desired to be left in the water, the Brin's valve is opened further and *vice versa*.

To shut off SO_2 :—

Close the Brin's valve. If the plant is not likely to be working for some days, or if it is to be moved, close the valve next to the non-return valve (D) and also the cylinder valve.

(x). *Backflushing after Filtration.*

This operation is generally performed if the pressure on the sand-filter has increased very considerably, or when work is finished for the day.

Shut off chlorine and sulphur dioxide as directed in operations vii and ix.

Close drain valves from :—

Laboratory sink (A2).
Funnel below sand-filter air-release pipe (A1).

Immediately the latter is closed :—

Open sand-filter valve (SF2) and *close* (SF3).
Open sand-filter valve (SF4) and *close* (SF1).
Open valve (AV1) on sand-filter air-release pipe fully.

(xi). *Changing to Filter.*

When drain shows clear water, operation v is carried out again and also the subsequent operations as described.

(xii). *Draining* (after backflushing has been carried out).

Instruct man to stop the engine.
Close valve (AV) on alum supply to pump, if open.
Close the bypass (BP).
Open the drain valves from :—

Chlorine diffuser cylinder (CDD).
SO_2 diffuser cylinder (DDD).
Contact tank (CT).
Alum tank (AD) (only if moving the plant), thus economizing alum solution.

Also *open* air-release valve on chlorine diffuser cylinder and on sand-filter after water in contact tank has fallen below the level of this outlet.

Note.—The drain valves from :—

(*a*) Laboratory sink, funnel below engine circulation overflow, funnel below sand-filter air-release pipe must be kept closed during draining and backflushing to prevent flooding, but towards the end of the operation of draining they may be advantageously opened.

(*b*) After draining has been going on for some time, the engine circulation should be drained by opening all valves on the engine-cooling system, and also the valve (CWD) on engine.

(c) In frosty weather draining must be carried to completion, and, when finished, the R.A.S.C. man must run the engine and pump for a few minutes (with all water drained) so as to remove as much water as possible from the pump and water jacket. It is advisable to pour into the pump 250 c.c. of either methylated spirits or anti-freezing compound. By this means the engine and pump are always ready to start, and no thawing is required.

(xiii). *Caution.*

1. Before starting always go over all valves twice to avoid mistakes.
2. If pressure rises above 15 lb., at once open bypass and then backflush; then go over machine to discover possible mistakes of manipulation.
3. If you discover anything wrong with the engine or pump, at once inform the man in charge.
4. It will usually be necessary to backflush for about 20 minutes before finishing work.
5. See that the chlorine and sulphur dioxide cylinders' main valves are shut when the lorry is moved.
6. Always see that a box respirator is hung in a prominent place in the laboratory.
7. Always look for leaks of both chlorine and sulphur dioxide with a bottle of ammonia. White fumes indicate a leak.
8. In cold weather, when pressure in the chlorine cylinder drops below 45 lb. the cupboard in which the cylinders that are in use are kept, and also the instrument, must be warmed by means of a paraffin lamp. Care should be taken to prevent any chance of fire by overheating, and every effort should be made to see that the instrument is not allowed to get colder than the cylinder, as otherwise chlorine will liquefy in it.

(xiv). *Chemical Control of Machine.*

In the laboratory are four taps which supply samples of :—
(1) Filtered water.
(2) Water immediately after chlorination.
(3) Water after passing through contact tank.
(4) Water after it has been dechlorinated with SO_2.

A sample from (1) will indicate the efficiency of the filter.

If the water is not clear, alum must be added as described in operation v. The alum should be added at the smallest necessary rate, and observation kept on the effect. As a rule the solution should be made by dissolving 2½ oz. of aluminium sulphate in a gallon of water, and the rate at which this solution is used should be noted by observation of the time taken for the level of the solution in the alum tank to be lowered by, say, half an inch. Running alum in at the rate of one grain per gallon, using the above solution, the tank should empty at the rate of 2 in. per hour.

A sample taken from (2), and treated as in operation ix, will always show less chlorine in solution than is indicated by the reading on the Wallace-Tiernan instrument, as quite a large quantity of chlorine is used up immediately it comes in contact with water. This chlorine estimation, however, always gives a check on the instrument, and will immediately show if it is faulty.

A sample taken from (3), and treated as in operation ix, will give a reading of the amount of chlorine in the water after it has passed through the contact tank. For contaminated water requiring about two to four parts of chlorine per million, it is generally found that for complete sterilization of this water the reading should not be less than 1·8 parts of chlorine per million.

Samples taken from (4) will be used in order to determine the amount of sulphur dioxide to be added, a process of trial by error being used. That is to say, if the reading of a sample of water from (4) is too high in chlorine, then the fine adjustment or regulating valve is opened to allow more sulphur dioxide to pass, and *vice versa.*

For immediate use the water might easily contain only 0·2 part of chlorine per million. If a solution of potassium iodide and starch is added to water containing only this amount of chlorine, a faint blue colour is imparted.

Note.—If water does not run from tap F3 (after contact) and tap 4 (dechlorinated) it will be necessary to close the final effluent valve D or D2 slightly in order to produce a sufficient pressure to force water from these taps.

(xv). *Preparation of Potassium Iodide and Starch Solution.*

Shake up 5 grams of starch in a test tube half full of water till thoroughly mixed. Add this to about 150 c.c. of boiling water and stir until the mixture just commences to boil. Add 5 grams of potassium iodide to 500 c.c. of chlorine free water, pour in the starch solution, and make up to 1 litre. Add one or two drops of oil of cassia if the solution is likely to be kept for more than two days. A few drops of this solution is all that is required for each test; care should be taken to prevent waste.

(xvi). *Instructions for Use of Water Sterilization Testing Case with Mobile Sterilization Plant.*

Description of Contents.—The contents of the case are as follows :—

Six white enamelled cups, holding $\frac{1}{3}$ pint of water when filled to the brim.

One black enamelled cup with mark on inside.

Two metal spoons, each holding 2 grams when filled with bleaching powder level with the brim. They are similar to the measure contained in the $\frac{1}{4}$-lb. tins of bleaching powder.

One stock bottle of zinc iodide and starch test solution and one dropping bottle. Three drops of the solution give a definite blue colour with water containing one part of free chlorine per million.

Six glass tubes or pipettes, each of such dimensions that a drop of standard bleaching powder solution delivered by it, when held in a vertical position, into a white cup filled with water gives a dilution of chlorine of one part per million.

Four glass stirring rods.

Twelve pipe cleaners.

Two copies of instructions.

Method of Using.—Crude water is generally used. The test is best carried out while the plant is being got ready to work. This test takes about half an hour to carry out.

1. Prepare a standard solution of bleaching powder in the black cup as follows :—Put into the black cup one level spoonful of good bleaching powder, make it into a smooth paste with a little water by stirring it with a glass stirrer, and carefully breaking up all lumps. Add more water to the paste and fill the black cup with water to the mark on the inside. Stir vigorously and leave the glass rod in the black cup. This solution is never clear, as it contains lime in suspension, which, however, gradually settles.

2. Fill the six white cups with water to be tested to within a $\frac{1}{4}$-in. of the top.

3. Add drops of the standard bleaching powder solution from the pipette to the water in the white cups so that they contain one, two, three, four, five and six drops respectively. Stir each thoroughly with a clean stirring rod and leave this stirring rod in one of the cups. Allow the cups to stand for half an hour.

Note.—In order to add even drops of the standard bleaching powder solution to the cups, it is necessary that the top of the pipette, and also the finger, should be quite dry. Pressure of the finger on the pipette keeps the liquid from running out. By gradually releasing the pressure a continuous series of drops can be made to fall from the pipette. A novice can soon learn the method of dropping by practising a few times with the solution out of the black cup.

4. *After* half an hour add three drops of the zinc iodide and starch test solution from the dropping bottle, or directly from the stock bottle, to each of the white cups and stir each with the stirring rod left in one of the cups.

5. Some of the six white cups will show no colour, some will show a blue colour. *The first of the cups showing a blue colour*, that is, the one containing the smallest number of drops, is noted. Say cups 1, 2, 3 show no colour, but cups 4, 5, 6 show a blue colour, then cup No. 4 is the one to be noted. The water therefore requires four parts of chlorine per million to sterilize it. If none of the cups show a blue colour, the cups are washed out and the test is performed again with 7, 8, 9, 10, 11, 12 drops of the bleaching powder solution in the cups

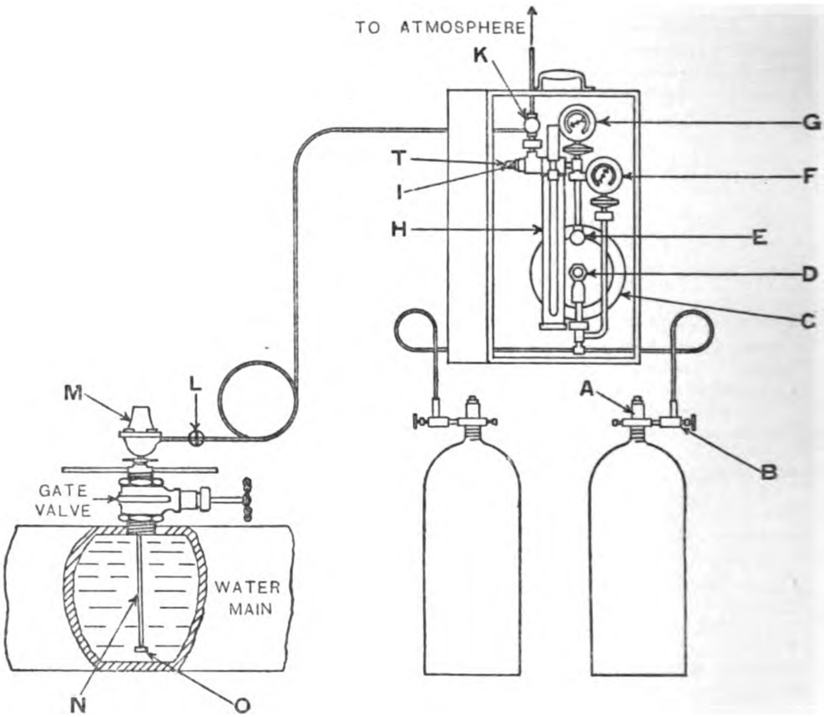

Fig. 3.—Diagram of direct-feed manual control chlorinator (Wallace-Tiernan).

6. Each drop of bleaching powder solution in a white cup corresponds to one part of chlorine per million.

It is to be noted that only if the bleaching powder is fresh and good will this test accurately agree with the amounts of free chlorine required for sterilization. It will, however, generally serve as a guide for the amount of chlorine to be used.

It will be found that at least 1·8 parts of chlorine per million must be present in the water when it leaves the contact tank in order to ensure sterility.

It should be remembered that if it is desired to increase the output of the machine for a short period, then a much larger dose of chlorine must be administered to make up for the shorter period of contact in order to maintain a supply of sterile water.

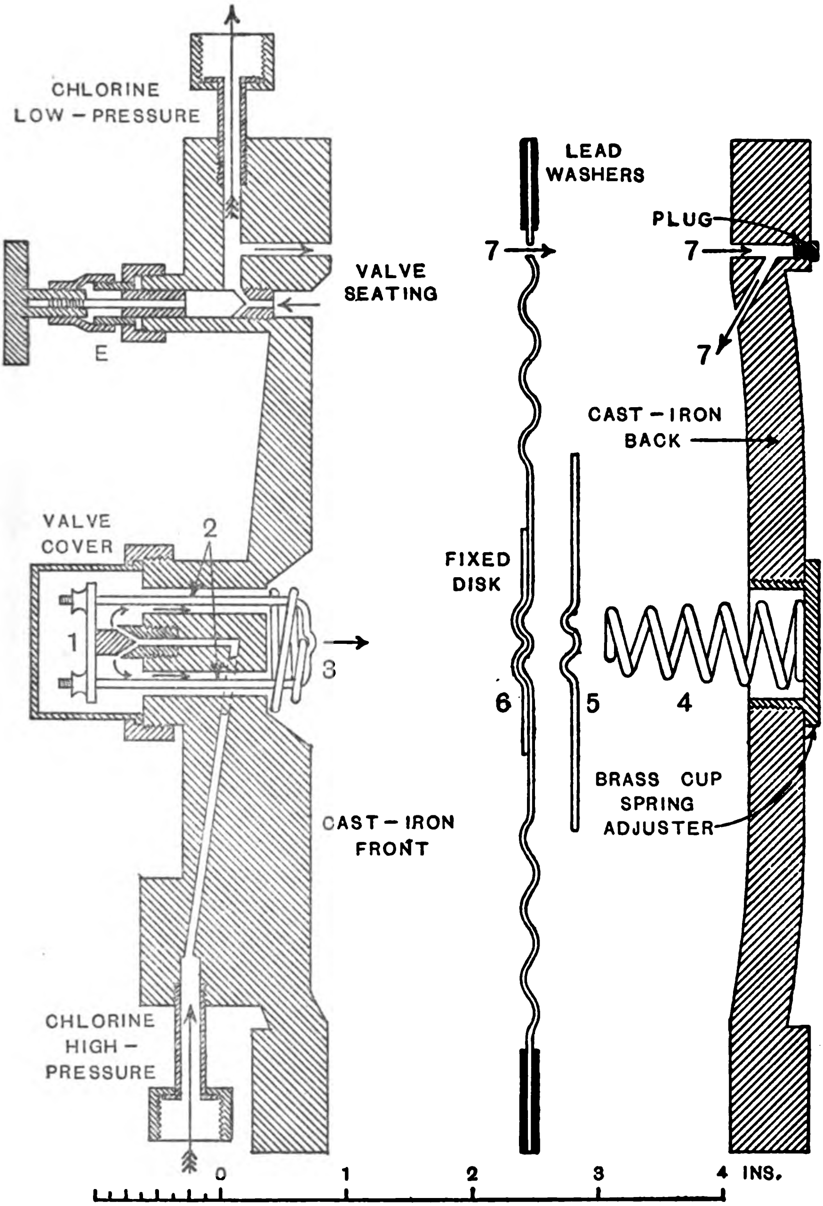

Fig. 4.—Compensator (C, Fig. 3) in section, separated.
(Wallace-Tiernan Chlorinator.)

(xvii). *Description and Method of using the Wallace-Tiernan Chlorinator.*

Description of Principle.—The apparatus is essentially one which meters chlorine gas, and which at the same time delivers the gas at a constant pressure.

Chlorine is stored in steel cylinders as a liquid, and the pressure within such a cylinder will depend upon the temperature at which the cylinder happens to be. That is to say, the pressure registered within a cylinder

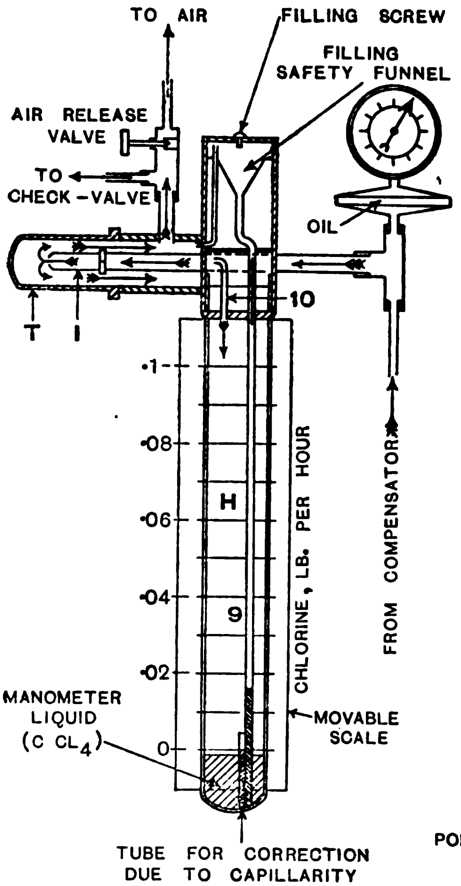

Fig. 5.—Orifice (I, Fig. 3) and manometer (H, Fig. 3).

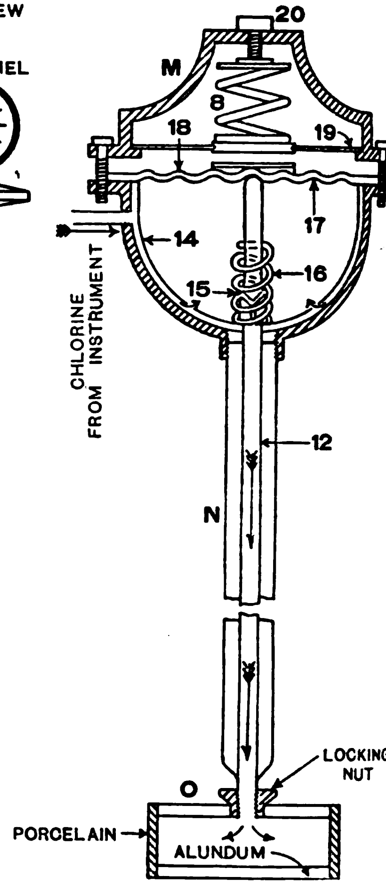

Fig. 6.—Check-valve (M, Fig. 3) and diffuser (O, Fig. 3).

(Wallace-Tiernan Chlorinator.)

of liquid chlorine is the pressure which the vapour of liquid chlorine, that is, chlorine gas, exerts while in contact with liquid chlorine at the temperature of the cylinder and contents. A rise in temperature will produce an increase of pressure and *vice versa.*

Another factor also affects the pressure within the chlorine cylinder. If gaseous chlorine is allowed to escape by opening the valve, the liquid chlorine must necessarily evaporate to account for this escape. Liquid chlorine is

an extremely bad conductor of heat, and consequently most of the latent heat required to evaporate the liquid chlorine will be obtained from the chlorine itself, and not from the surrounding atmosphere, consequently the temperature of the chlorine inside the cylinder will fall, and thus produce a fall in pressure.

It should be noted that with a lower temperature the density of the chlorine will be greater, and consequently for the same volume passing through the instrument a greater mass will also pass.

The Wallace-Tiernan Chlorinator (Fig. 3) is actually a reducing valve and meter, and consists of three main portions :—

(1) The *compensator* (Fig. 4), in which alterations of pressure in the cylinder are compensated.

(2) The metering or flow-measuring apparatus (Fig. 5).

(3) The *check valve*—or back-pressure valve—and *diffusor* (Fig. 6).

Explanation of Working.—Under all normal conditions in commencing work with the chlorinator, the valve on the cylinder (A) and auxiliary tank valve (B), control valve (E), blow-off valve (K) and auxiliary valve on check valve (L) are shut. Open valve (L) and main tank valve (A). See that control valve (E) is closed. Open auxiliary tank valve (B) *slowly*.

Chlorine now enters the compensator (C) through the small needle valve (1) and passes down the two holes (2) and fills the space between the front portion of the compensator and the silver diaphragm (6).

The pressure in this space increases and forces back the silver diaphragm (6) and the strengthening disc (5) against the spring (4), and at the same time allows spring to close needle valve (1).

The pressure of the gas in the cylinder is registered on the tank pressure gauge (F). The control valve (E) is now slowly opened, and chlorine will pass through this valve and slowly build up a pressure which will be registered on the back pressure gauge (G). This pressure will be exerted on the back of the silver diaphragm (6), as there is a small hole (7) drilled through the apparatus for this purpose.

During this operation great care must be taken to open the control valve (E) only sufficiently to cause the liquid in the manometer (H) tube to rise in the small inner tube and be seen. If opened too much the liquid in the manometer tube will be driven out and possibly get into the orifice and cap (I and T) or into the compensator.

As chlorine passes through the control valve (E) the pressure on the front side of the diaphragm (6) will fall, consequently the pressure on the back side of this diaphragm (due to spring (4) and the " back-pressure ") will cause the diaphragm (6) to press on the needle valve (I) and allow more chlorine to enter through this valve.

When the back-pressure, which is determined by setting the spring in the check valve (M), is reached, and indicated by the back-pressure gauge (G), a state of equilibrium is maintained in the compensator.

Any chlorine passing out of the compensator will tend to increase pressure on check valve (M), and more chlorine will consequently pass through needle valve (I), due to the slight breathing effect of the silver diaphragms.

Thus a steady flow of chlorine is maintained.

(xviii). *Manometer.*

The outer tube of the manometer (H) is connected to the orifice (I) and the small tube to the orifice-cap (T). As chlorine flows along and meets the orifice it is necessarily checked in its flow, and consequently the pressure will increase before it passes through the orifice ; a corresponding decrease will be observed immediately after passing through the orifice. This difference is proportional to the flow, and consequently the manometer readings will indicate the rate of flow of chlorine. The scale of reading is determined experimentally by the manufacturer for each orifice used.

A small tube is attached to the inner tube for the purpose of correcting for capillarity and to enable readings to be made more easily.

(xix). *Check Valve.*

The check valve consists of a silver-plated brass or copper stem through which runs a silver tube (12). To the open end of this tube is attached the diffuser (O), which consists of a cylindrical ring of porcelain and two discs of carborundum (in all probability this is really alundum, a semi-fused form of aluminium oxide).

The other end is attached to a perforated silver hemisphere (14) fitting inside the main portion of the valve, and fitted with a needle valve which is kept open by a spring (16).

Closing this hemisphere is a silver corrugated disc (17), with a similar disc of copper (18) on the top of it for strength.

Acting on this is a spring (8) which is fitted to a segmented disc of brass (19), so allowing for adjustment.

The spring (8) is set for whatever back-pressure is desired, and the needle valve (15) will remain closed until the pressure inside is sufficient to lift the diaphragm and so allow the needle valve to open.

The pressure necessary for this is of course adjusted by the tension of the spring (8).

Note.—(1) Cylinders of chlorine for use with this type of Wallace-Tiernan apparatus should be without central syphon tube. If by chance these are not available then the cylinder must be used upside down, as it is essential that chlorine gas only enters the instrument. This also applies to the cylinders of SO_2.

(2) Some diagrams show "gate valves." This valve is only fitted if it is desired to remove the diffuser from the plant without emptying water.

(3) In cold weather it is advisable to keep lamps near the cylinder and the instrument if the tank pressure falls below 45 lb. It is essential that the instrument be kept at least as warm as the cylinder; it must never be colder, or else chlorine will liquefy in the compensator. When this happens the reading on the manometer will be constantly varying. A lamp must be placed near the instrument in order to warm it, and thus remedy this defect. Draughts will often produce this cooling.

(4) It may sometimes happen that a cylinder without a syphon tube is empty, and only a full one with a syphon tube is available for use. In this case connect the two together both in a vertical position, by means of a copper tube and the necessary fittings. Keep the syphon-tube cylinder warmer than the other cylinder, and open both valves. Chlorine will pass from the warmer to the cooler cylinder very quickly, and can be actually checked by weighing.

(5) Never, under any circumstances, leave the instrument in such a way that the atmosphere can get to the inside of any part of it; corrosion will inevitably take place and cause much trouble.

(xx). *Conversion Table showing lbs. of Chlorine per Hour.*

Parts per million.	Gallons of Water per Hour.												
	400	500	600	700	800	900	1000	1100	1200	1300	1400	1500	1600
1....	·004	·005	·006	·007	·008	·009	·01	·011	·012	·013	·014	·015	·016
2....	·008	·01	·012	·014	·016	·018	·02	·022	·024	·026	·028	·03	·032
3....	·012	·015	·018	·021	·024	·027	·03	·033	·036	·039	·042	·045	·048
4....	·016	·02	·024	·028	·032	·036	·04	·044	·048	·052	·056	·06	·064
5....	·02	·025	·030	·035	·04	·045	·05	·055	·06	·065	·07	·075	·08
6....	·024	·03	·036	·042	·048	·054	·06	·066	·072	·078	·084	·09	·096
7....	·028	·035	·042	·049	·056	·063	·07	·077	·084	·091	·098	·105	·112
8....	·032	·04	·048	·056	·064	·072	·08	·088	·096	·104	·112	·12	·128
9....	·036	·045	·054	·063	·072	·081	·09	·099	·108	·117	·126	·135	·144
10....	·04	·05	·06	·07	·08	·09	·1	·11	·12	·13	·14	·15	·16
11....	·044	·055	·066	·077	·088	·099	·11	·121	·132	·143	·154	·165	·176
12....	·048	·06	·072	·084	·096	·108	·12	·132	·144	·156	·168	·18	·192

4.—*Instructions for Chemists employed on Water Purification Duties.*

In order to minimize the possibility of the water being poisoned, it is necessary in the case of barges that the neighbourhood shall be efficiently patrolled on both banks, and no one, not even a child, should be allowed to approach within a distance of a hundred yards of the water on either side of the barge.

If possible a couple of dogs should be kept on the barge for tests on the potability of the water and as aids to the guards. The appearance of dead fish in the neighbourhood of the barge should be looked for.

The water should be tested every hour. The poisons which will most probably be employed are salts of lead, copper, mercury and arsenic, and soluble cyanides. If poisons are found, the pumps should at once be stopped and all water run out of the tanks.

The poison must be identified and estimated. For identification the following procedure is to be used :—

To a cylinder full of the water add a few drops of sodium sulphide solution. A brown or black coloration indicates lead, copper or mercury. It is possible to detect thus :—

(*a*) Less than 1 mgm. $Pb(NO_3)_2$ per litre ;
(*b*) Less than 1 mgm. $CuSO_4, 5H_2O$ per litre ; or
(*c*) 2 mgm. $HgCl_2$ per litre.

Lead can be identified by adding a few drops of acetic acid and then potassium chromate to a cylinder full of the water. It will show a distinct opalescence when viewed against a dark background if 2 mgm. of $Pb(NO_3)_2$ per litre is present.

To test for copper add a few drops of acetic acid and then potassium ferrocyanide. If 1 mgm. $CuSo_4, 5H_2O$ per litre is present a distinct colouration will be noticeable.

If lead and copper have been proved to be absent and sodium sulphide gives a black colouration, mercury must be assumed.

Arsenic as arsen*ite* is detected by adding sodium sulphide and then acidifying with sulphuric acid. A yellow coloration is given by less than 1 mgm. of As_2O_3 per litre. Arsenic as arsen*ite* or arsen*ate* is detected by Marsh's apparatus, using hydrochloric acid and pure zinc. Blank tests must always be made. If 10 c.c. of the water is used Marsh's test will detect :

(*a*) less than 1 mgm. As_2O_3 per litre.
(*b*) 1 mgm. sodium arsenate (Na_2HAsO_4) per litre.

Cyanide is detected by means of a dilute $\frac{N}{100}$ solution of silver nitrate, preferably added from a burette slowly. The water is previously made strongly alkaline by the addition of caustic soda. The appearance of a momentary white turbidity, which redissolves at once, indicates cyanide. AgCN is first produced and this dissolves in presence of alkaline cyanide to give the soluble salt AgCN . KCN. The presence of chloride does not interfere with the action. By using 200 c.c. of the water 1 to 2 mgm. KCN per litre can be detected.

As it is possible that alkaloid poisoning may be resorted to, the water should be continually tested with phosphotungstic acid. A white flocculent precipitate, which, however, is also produced by albuminous matter, makes the potability of the water doubtful. A further test should be made for alkaloids by the addition of potassium tri-iodide. This reagent is made by dissolving 12·7 gm. iodine and 60 gm. potassium iodide in 1 litre of water. A reddish-brown precipitate will confirm the presence of alkaloids. If these are found the barge should at once be moved and the tanks emptied.

The average lethal dose of each of the poisons, as nearly as it can be estimated, is given below :—

Lead	2 gm. $Pb(NO_3)_2$
Copper	1 gm. $CuSO_4 . 5H_2O$
Mercury	0·2 gm. $HgCl_2$
Arsenic	0·1 gm. As_2O_3
Cyanide	0·3 gm. KCN.

The procedure for estimating and removing any poison which may have been found is given under the corresponding heading below.

Lead.

Estimation.—A cylinder full of the water must be acidified with hydrochloric acid and a small quantity of sodium sulphide added. The brown or black colour is compared with that of a similar column of water to which a known quantity of a solution of lead nitrate has been added. By matching the colour the amount of metal can be estimated. Comparison is best made with a solution of $Pb(NO_3)_2$ containing 2 mgm. per litre.

Removal.—Lead is to be removed as sulphide by the addition of alum and sodium sulphide. The alum acts as a coagulant and must be added *first*. The amount of alum necessary is between 20 and 30 mgm. per litre. The amount of sodium sulphide necessary is calculated and a quantity slightly in excess of that amount is added.

The minimum time that must be allowed to elapse between addition of the reagents and filtration is 15 minutes. The removal of lead is complete even at a dilution of 10 mgm. per litre.

1 gm. $Pb(NO_3)_2$ per litre requires 28·8 lb. Na_2S, $9H_2O$ per 4,000 gal.

1 gm. Pb per litre requires 46·0 lb. Na_2S, $9H_2O$ per 4,000 gal.

Alum required is 1 lb. per 4,000 gal. whatever the concentration of lead.

In all cases where moist sodium sulphide is used (it is slightly deliquescent) an excess of 7 per cent. over the above amounts should be added.

Mercury.

Estimation.—Exactly as for lead or copper. Comparison is best made with a solution of $HgCl_2$ containing 5 mgm. per litre.

Removal.—Mercury is removed as sulphide by the addition of alum and sodium sulphide. The alum must be added first, then the sodium sulphide in slight excess. At least 15 minutes must be allowed to elapse between addition of the reagents and filtration. The removal of mercury is complete even at a dilution of 10 mgm. $HgCl_2$ per litre.

1 gm. $HgCl_2$ per litre requires 35·1 lb. Na_2S, $9H_2O$ per 4,000 gal.

1 gm. Hg per litre requires 47·6 lb. Na_2S, $9H_2O$ per 4,000 gal.

One lb. alum is added to every 4,000 gal., whatever the concentration of the mercury.

Arsenic.

Estimation.—Arsenic present as arsenite is estimated first. This is done colorimetrically. The water is acidified with sulphuric acid and a few drops of sodium sulphide solution are added. The tint produced is compared with that formed in the same way from a solution of arsenite of known strength. The best strength of the comparison solution is from 2 to 3 mgm. As_2O_3 per litre.

The total arsenic present is then estimated by Marsh's apparatus, using hydrochloric acid and pure zinc which works with arsenate as well as with arsenite. A set of standard mirrors must be previously prepared from known amounts of As_2O_3 ranging from 0·001 to 0·01 mgm. 10 c.c. of the water is to be used for each test. If this yields too strong a mirror the water must be suitably diluted. In every case a blank test must be made.

Removal.—Arsenic is removed as basic ferric arsenate. If wholly present as arsenate all that is necessary is the addition of the correct amount of iron

alum. 0·3 gm. of sodium arsenate requires 1 gm. of iron alum for complete precipitation ; 15 minutes contact is required before the arsenic is completely precipitated and therefore this is the minimum time that must be allowed to elapse between addition of the iron alum and filtration. The removal of arsenate is complete even at a dilution of 10 mgm. Na_2HAsO_4, $7H_2O$ per litre, the resulting water being free from both arsenate and iron. If, however, the concentration of arsenate is greater than 4 gm. Na_2HAsO_4, $7H_2O$ per litre addition of lime as described below under arsenite is necessary.

1 gm. Na_2HAsO_4, $7H_2O$ per litre requires 132·3 lb. iron alum per 4,000 gal.
1 gm. As per litre requires 525·7 lb. iron alum per 4,000 gal.

This latter figure is only for calculation purposes. The possible amount may be assumed as $\frac{1}{10}$ of 1 gr. As_2O_3. Taking 52·5 lb. as the maximum amount required, 25 gal. water would be required.

If the arsenic is present as arsenite, it must be oxidized to arsenate by addition of the requisite quantity of bleaching powder before precipitation with iron alum.

The bleaching powder is added in slight excess as shown by starch-iodide paper, and is allowed to act on the arsenite for at least four minutes before the addition of iron alum. The quantity of iron alum necessary for complete precipitation is not proportional to the amount of arsenite present, but falls off with increasing concentration. This is due to the fact that in the stronger solutions some of the arsenate is precipitated as calcium arsenate. The quantities of iron alum necessary for various quantities of arsenite in the original solution are given in the table below. Further, since the addition of iron alum tends to make the solution acid, it is necessary with solutions containing more than 150 mgm. As_2O_3 per litre, and advisable in all cases, to add some free lime with the bleaching powder. A quantity equal to about one-fifth the weight of the bleaching powder is sufficient, provided the original solution is neutral. If it is acid, a corresponding increase must be made in the amount of lime added.

The table below gives the necessary quantities of the reagents in lbs. per 4,000 gal. for varying quantities of arsenic. The bleaching powder is calculated for a sample containing 25·5 per cent. available chlorine.

Calculated Quantities in lb./4,000 gal.

As_2O_3 in grm./litre.	$CaOCl_2$ in lb./4,000 gal.	Lime in lb./4,000 gal.	Iron alum in lb./4,000 gal.
·005 grm.	·67 lb.	·12 lb.	3·18 lb.
·01 ,,	1·39 ,,	·28 ,,	6·36 ,,
·02 ,,	2·78 ,,	·56 ,,	12·7 ,,
·035 ,,	4·77 ,,	·96 ,,	22·2 ,,
·05 ,,	6·36 ,,	1·27 ,,	27·8 ,,
·075 ,,	9·53 ,,	1·91 ,,	31·8 ,,
·10 ,,	12·3 ,,	2·5 ,,	35·7 ,,
·15 ,,	19·1 ,,	3·8 ,,	45·7 ,,
·20 ,,	24·6 ,,	4·8 ,,	55·6 ,,
·25 ,,	31·0 ,,	6·8 ,,	65·6 ,,
·30 ,,	37·0 ,,	7·6 ,,	75·5 ,,
·35 ,,	43·3 ,,	8·8 ,,	85·4 ,,
·40 ,,	49·3 ,,	9·9 ,,	97·3 ,,
·45 ,,	55·6 ,,	11·2 ,,	107·2 ,,
·50 ,,	61·6 ,,	12·4 ,,	119·0 ,,

Cyanide.

Estimation.—This is on the same principle as that for the detection. A standard $\frac{N}{100}$ solution of $AgNO_3$ is used, and this is added from a burette, gradually, to the alkaline sample of water (a measured amount) until the point is reached when a slight *permanent* opalescence is produced. This is taken as the point when the formation of the body KCN AgCN is complete, so that

$$1 \text{ c.c. } AgNO_3 \frac{N}{100} = 1\cdot3 \text{ mgm. of KCN.}$$

It is essential in this estimation that the sample of water be perfectly clear otherwise the precipitated silver salt will coagulate on any sediment present, and the opalescence will disappear. If possible, the titration should be done against a black background. Chloride does not affect the estimation, but rather tends to intensify the end-point.

Removal.—This depends on the formation of potassic-ferrous ferrocyanide, $K_2Fe[Fe(CN)6]$, and *not* prussian blue. It is necessary for complete removal of cyanide to have a little alkali present, since this depresses the amount of free HCN in the solution. Free HCN does not readily act on ferrous salts, but with alkali present the reaction goes to completion :—

$$6KCN + 2FeSO_4 = K_2Fe\,[Fe(CN)6] + K_2SO_4.$$

The reaction, however, is not theoretical, and a table of quantities has accordingly been drawn up. Of course, the alkali added has to be destroyed by addition of the requisite excess of ferrous sulphate, so that the precipitate obtained contains quantities of ferrous hydroxide in addition to the cyanogen compound.

If alkali in excess is added, the filtrate will be yellow, due to the presence of ferrocyanide, but as this is harmless, it is preferable to having excess of iron, since in the latter case the liquid gets muddy after filtration through oxidation of the ferrous sulphate to various hydrates of iron. The precipitate itself (left on the sand) oxidizes gradually in the air with liberation of potassium ferrocyanide, so that, where possible, the sand should be washed before each filtration. By the above treatment it is found possible to remove cyanide down to about 5 mgm. per litre, *i.e.*, 0·35 gr. per gal., which means that a man would drink the lethal dose (5 gr.) in about 14 gal.

The caustic soda must be added first, and the ferrous sulphate to the alkaline water. The iron and caustic soda solutions are made separately in the small mixing tanks and arranged so as to run out at the rate required. The solutions will run separately into the large treatment tank, where they meet the contaminated water, which enters at the known rate of 4,000 gal. per hour. By the time the treated water reaches the top outlet of the tank about 10 minutes will have elapsed, by which time the precipitate will have coagulated, fit for filtration.

The following table gives the amounts of caustic soda and ferrous sulphate to be added per hour (in the case of the barges) for a water delivery of 4,000 gal. per hour, assuming various concentrations of cyanide per litre :—

KCN in mg. per litre.		*$FeSO_4 7H_2O$ in lb. per 4,000 gal. per hour.*
10 mg.	..	23½ lb.
20 ,,	..	24 ,,
50 ,,	..	26½ ,,
100 ,,	..	32 ,,
150 ,,	..	36½ ,,
200 ,,	..	42 ,,
250 ,,	..	46½ ,,
300 ,,	..	52 ,,
350 ,,	..	57 ,,
400 ,,	..	61 ,,
450 ,,	..	56½ ,,
500 ,,	..	69½ ,,

The amount of NaOH to be added is constant for all concentrations, and is 7 lb. NaOH per 4,000 gal. per hour.

Copper.

Estimation.—Exactly as for lead. Comparison is best made with solution of $CuSO_4$, $5H_2O$ containing 5 mgm. per litre.

Removal.—Copper is removed as hydroxide by the addition of lime. For every 5 gm. of $CuSO_4$, $5H_2O$, 6 gm. of lime are to be added. The copper is removed to less than 1 mgm. $CuSO_4$, $5H_2O$ per litre at dilutions down to 10 mgm. per litre.

1 gm. $CuSO_4$, $5H_2O$ per litre requires 47·7 lb. lime per 4,000 gal.

5.—*Mule Pack Filter.*

Crude water is treated with bleaching powder and alum solution and filtered through crushed flint (silex).

The apparatus consists of two cylindrical tanks mounted one above the other on a collapsible stand. The upper cylindrical tank is divided into two vertical compartments, each having a capacity of 27·5 litres (six gallons). These two compartments serve to hold the crude water, and are connected at the bottom by a three-way tap, so arranged that while the water from one compartment is passing to the silex in the lower cylindrical tank, the other compartment can be filled with crude water and treated with aluminium sulphate and bleaching powder.

By reversing the direction of the tap, when one compartment is emptied, the water in the other compartment passes to the silex, and a continuous method of working can be carried out.

A gauze strainer is fitted to the filling hole of each compartment.

The lower cylindrical tank is divided horizontally into two portions—the upper portion containing the special filtering material, silex or crushed flint, and the lower portion, fitted with taps, serving as a distributor and container for purified water.

This lower cylinder is constructed so that it is pivoted on axles and can be rotated so as to cause the purified water from the bottom of this cylinder to retrace its path and backwash the silex, and thus remove the material which has been filtered from the water.

A small pump is attached for pumping water to the upper cylinder.

Method of Use.—The stand is joined together by bolting as indicated by the lettering. The top cylinder is bolted to the frame, the lower cylinder placed on its supports, and the silex levelled. The top of the lower cylinder is bolted in position and the three-way tap between the two cylinders connected to the brass pipe of the lower cylinder is closed so as to shut both compartments of the upper tank. The apparatus is now ready for use.

One compartment of the top tank is then filled, and during the filling, 50 c.c. of alum solution (30 gm. per litre), and the requisite quantity of bleaching powder solution as shown by the water case testing (5 c.c. of the black cup solution equals one part per 1,000,000 of free chlorine) is added. After standing 10 minutes the three-way tap is opened and the water passes into a gauze box, which distributes the water evenly over the surface of the silex.

The water passes through the silex, which is placed upon the gauze grid, through this grid, and then up through the outer of the two concentric tubes, and finally down the centre tube into the bottom portion of the lower cylinder.

It will be observed that the filter works under very little pressure, actually about 2-in. head of water and the three-way tap may require a little adjustment on opening at first in order to prevent more water entering the top of the silex than can be filtered. Water coming out of the top of the lower cylindrical tank indicates this, and it is necessary to close the three-way tap a little until water just ceases to come out of the top. It takes about four minutes for water to pass through the filter at commencement.

Whilst the first compartment is filtering, the other compartment is filled with water and treated as above. When the first compartment is empty, by changing the tap, the water in the other compartment may be allowed

to filter, whilst the first is again re-filling. The filter thus works nearly continuously.

It will be found that after some hours' continuous use the rate of filtration will be much slower, especially if the water to be filtered is very dirty. The filter is not so efficient when this is the case, and it becomes necessary to wash the silex. This is best done by removing the top of the lower cylinder, and adding clean water from time to time, thoroughly stirring up the silex and pouring away the dirty water. This must be repeated until no further dirt can be removed. When completed, bolt on the lid of the cylinder, connect the tap, and commence as before.

After this flushing, it will always take a little time before the filtered water is quite clear. For average working, the filter will deliver two gallons in from two to three minutes, and generally, if the time is greater than six minutes, it is an indication that the silex requires washing.

With water containing about 25 to 30 parts per 100,000 of suspended matter, the plant can be run continuously for about six to eight hours, sterilizing and filtering.

Small Filter for Hand Carriage.

This filter consists of a canvas reservoir, which is suspended above a silex filter, similar to the one in the mule pack filter. The reservoir is filled with water, and the requisite amount of alum and bleaching powder added. The whole is stirred up and allowed to stand for 10, or preferably 20, minutes. The filter tap is then turned on, the water passes through the filter and is ready for use.

APPENDIX C.

REPORT ON WATER REQUIREMENTS FOR AN ADVANCE IN FLANDERS.*

In estimating the requirements of the troops the most difficult tract in Belgium has been examined, and for the purposes of this report the country to be traversed has been taken as the zone bounded on the north by Roulers, Thielt, Ghent, Malines; on the east by Malines, Brussels, Charleroi; and on the south by Charleroi, Mons, Valenciennes and Douai.

This tract, which measures approximately 70 miles by 45 miles, includes parts of the low-lying region of east and west Flanders in which the difficulties of the provision of drinking water are most accentuated because it would be necessary to depend almost entirely on surface supplies.

Outside this area the difficulties of supplying water to troops would be considerably lessened.

In respect of water supply the most notable points in this area are these:—

(*a*) In the region Béthune-Lille-Roubaix-Douai there exists a large number of deep wells drawing water, which is generally of potable quality, from the chalk formation.

(*b*) In the area Ypres-Roulers-Thielt-Courtrai the supplies are scanty, especially in summer, as then many of the streams dry up.

(*c*) The courses of the rivers Lys (section Courtrai—Deynze), Scheldt, Dendre and of the Charleroi-Brussels canal lie across the supposed line of advance, and define defensive lines which may possibly be occupied by the enemy. Their waters are so grossly polluted, not only by sewage and organic matter, but also by the discharges from factories on the banks, as to be unfit for consumption, even by animals in the summer season. Nevertheless, in this region,

* Extract from report of Committee appointed in France in May 1915, to report on water requirements during an advance in Flanders.

it is on wells in the vicinity of these waterways, in towns or otherwise, and on the river water itself after purification that it will be necessary to depend for the main supplies to the troops.

(*d*) The Scheldt below Ghent is tidal, and the water is therefore unfit for drinking; water from wells in the vicinity would be brackish.

(*e*) Information regarding the sources of supply is somewhat meagre. There is, however, sufficient evidence to show that almost all surface water may be regarded as contaminated or liable to contamination; and that arrangements must be made for sterilization. It is also known that many supplies, notably those from canals and rivers, will also need clarification.

From consideration of these conditions, it appears that the difficulties of supply of water would be greatest when troops, either on the march or concentrated for attack, approach a defensive line occupied by the enemy which corresponds with one of these water courses.

The requirements of the troops in regard to a particular area will also vary according to the circumstances of the troops whether

(*i*) on the move and in marching formations;

(*ii*) concentrated either for defence or attack; or, as at the present time, engaged in operations analogous to siege warfare, and therefore closely billeted or bivouacked; or

(*iii*) in reserve formations and in billets more widely spread, where the location of units can be made to conform with adequate sources of water supply.

In the case of troops on the move, it is clear that, where suitable water cannot be obtained *in situ*, difficulties of transport will necessarily limit the allowance to men and animals of drinking water to the absolute minimum required for the maintenance of physical strength. It is considered that for a short period, not exceeding three days, it will suffice to provide one-third of a gallon daily for each man, and two gallons for each animal.

In circumstances where the troops are stationary these minimum allowances should be increased to one gallon and three gallons respectively.

Another factor influencing the requirements of troops is the extent to which existing supplies may be destroyed by the enemy, either by demolition in the case of deep wells and of systems of distribution in towns, or by poisoning the water in the case of shallow wells, rivers, ponds and tanks.

In regard to deep wells, these could readily be destroyed by explosives, and except in Lille, Roubaix and Turcoing, they are not so numerous as to prevent this being done.

The universal poisoning of shallow wells throughout the whole tract of country in question cannot be regarded as a reasonable contingency. There are so many in certain localities that only a proportion of them are likely to be affected. The poison can easily be eliminated by continuous pumping, but the delay which would thus be entailed would serve the enemy's purpose, for they could not be counted on as supplies for a force on the march.

The poisoning of rivers with a current is not likely to be effective. The possibility cannot be neglected of the poisoning of short lengths of water in canals or canalized rivers, but the effect would be transient and such large quantities of poison would be required that this action is not greatly to be feared. Stagnant water in ponds could be poisoned with facility.

The General Staff have intimated that provision should be made for the advance of troops across this area allowing for the march of two divisions along a single road at the rate of ten miles a day.

From the foregoing it will be apparent that in many instances it will be necessary to arrange for the supply of water from sources within areas which, for some hours at least, have been occupied by our troops, and that such supplies will, in most cases, require to be clarified and sterilized before distribution. It is improbable that all our advanced troops will find locally supplies which are sufficient in quantity or fit for human consumption, even after treatment by the apparatus which regimental units possess.

System of Supply.

It is thought that the needs of the troops can best be gauged by an examination of the requirements of divisional formations (*a*) on the march; (*b*) concentrated; and (*c*) billeted in reserve; and that a water supply service would preferably conform to the divisional organization.

Troops on the March—Infantry Division—Men.

The system of supply recommended for adoption, working from rear to front, comprises the provision of:—

(*a*) Barges fitted with complete purifying plant, capable of a large output, from which water could either be drawn directly or delivered into.
(*b*) Water tank barges for conveyance of purified water to convenient distributing points.
(*c*) Motor lorries provided with purification plant, for use in places where barges cannot be taken, by reason of obstructions to navigation, or other causes.
(*d*) Motor cars fitted with water tanks, for distributing drinking water to the regimental water carts.
(*e*) Regimental horse-drawn water carts.

An Infantry Division Concentrated.

To meet the requirements of troops when concentrated, additional supplies of water will be required to increase the daily allowance to one gallon a head. In such circumstances it may reasonably be supposed that the roads and bridges up to within four or five miles of the front would have been made fit for the passage of motor lorries, and it would be advisable to provide lorries fitted with water tanks to effect this distribution.

An Infantry Division in Reserve Formations and Billets.

An infantry division in reserve formations and billets would normally depend upon existing sources, supplemented and improved by works carried out by the R.E. The provision of special plant and other stores is desirable, some of which have already been ordered. No additional transport equipment is necessary beyond that provided for troops concentrated.

Details of Distribution to an Infantry Division on the March.

The proposals in respect of distribution are based on the principle that at the beginning of each march in country of this character both the men's water bottles and the regimental water carts must be full.

From what has been said above it is clear that at the end of a march troops may be so distant from a source of supply that the regimental horsed water carts could not be taken to it for replenishment. Since the water carts must be filled again before the unit moves, it is proposed that water tank motor cars should be provided for this purpose, each holding approximately 100 gal. and light enough for passage over pontoon or temporary bridges. The supply could be carried out each day as soon as roads were clear of traffic or circulation by parallel roads becomes possible. Assuming a distance from the source not exceeding 12 to 15 miles, each motor car should be capable of performing two journeys before the commencement of the next march.

In certain localities these distances may be exceeded. A reserve of cars is desirable to meet special requirements.

With a view to reduction of First Line transport, it has been considered whether water tanks on motor cars could not be substituted for the horse-drawn vehicles with which all regimental units are now equipped, but the former are open to the following disadvantages:—

Motor cars could not move with First Line transport, for mechanical reasons, since they would be forced to travel on their lowest gearing.

Secondly, they could be seldom used off roads, and in many cases could not be taken close to sources of supply such as rivers, ponds and wells.

Since it seems essential that some water-carrying vehicles should always be present with the unit to carry a reserve of water, the retention of the horse-drawn water cart seems to be imperative.

Number of Vehicles required for an Infantry Division on the March.

Water Carts.—On the basis of a daily allowance of at least one-third of a gallon to each man in every unit, the number of regimental water carts allotted to a regular infantry division, constituted according to the War Establishments, should be increased from 60 to 85.

Allowing for unavoidable wastage, the total capacity of these carts may be taken as 8,500 gal.

The number of water carts in other divisions, of varying composition, should be increased proportionally.

Motor Water Tank Cars.—On the assumptions stated above, 43 water tank cars will be required to supply 8,500 gal. to regimental water carts. This number should be proportionately increased if it is not found possible to provide within a reasonable time cars of this water-carrying capacity, and if, in consequence, " Ford " cars with a lower capacity (say 60 to 70 gal.) are purchased.

Motor Lorries fitted with Purification Plant.—Each combined clarification and sterilization plant would be on one lorry, and would possess a capacity for output of 400 gal. an hour. Assuming five working hours daily in the circumstances stated, the output of each plant would be 2,000 gal. Thus for a demand of 8,500 gal. daily, five motor lorries would be required. Each poison-eliminating plant would be on a separate lorry and would give lower daily output, owing to the time required for the chemical treatment of poisoned water. It may be assumed, however, that only a proportion of the sources would be poisoned, and it is thought to be sufficient to allow for three motor lorries for this purpose.

Distribution to an Infantry Division Concentrated.

The system would be the same as for the supply of a division on the march, but in addition, in order to provide the troops with 1 gal. for each man, five motor lorries fitted with water tanks, each containing 600 gal., would be needed to supplement the supply conveyed in motor water tank cars. It is assumed that these lorries would perform two journeys daily and the cars three journeys in such circumstances.

Corps Troops on the March or Concentrated.

The same proportionate increase in the number of regimental water carts is recommended, the number being augmented from three to seven.

The purified supply being assumedly drawn in the main from barges or from local supplies, which there would have been time to treat, two motor water tank cars and one lorry fitted with a 600-gal. water tank would suffice for transport.

Details of Distribution to a Cavalry Division on the March.

A similar increase in the number of water carts allotted to each regular cavalry division is recommended to ensure one day's reserve of water at the commencement of a march.

Under the existing organization for food supplies cavalry is restricted to one day's radius of action from the head of the cavalry divisional supply column, which consists of 30-cwt. motor lorries. These vehicles are too heavy to pass over medium pontoon bridges, and in a country of this character, seamed with water-courses over which the permanent bridges will almost certainly have been destroyed, they would in all probability be unable to advance beyond the refilling points of infantry supply columns.

It seems unlikely, therefore, that cavalry on the march can be many miles ahead of the infantry formations. Accordingly it is proposed that the system of water-supply shall be similar to that of an infantry division, supplemented by the provision of poison-eliminating plant on horse-drawn vehicles, *if such is found to be effective,* for use in emergency. It is possible that in certain circumstances the mobility of cavalry might be largely increased thereby. But, irrespective of this plant, sufficient transport is necessary in the form of motor water tank cars to supply the whole personnel from a distant source.

Number of Vehicles required for a Cavalry Division on the March.

Water Carts.—An increase of 10 carts to the existing establishment is proposed, making a total of 29 carts, with a useful capacity of 2,900 gal.

Poison-eliminating Plant on Horse-drawn Carts.—Assuming a daily capacity of 400 gal. for each plant in three working hours, five plants on 10 four-horsed G.S. wagons are proposed.

Motor Water Tank Cars.—To transport in two trips 2,900 gal. in motor cars similar to those proposed for the infantry division, 15 cars should be provided.

Motor Lorries Fitted with Purification Plant.—Two plants of each type will be required for each division, similar to those provided for infantry divisions.

Cavalry Division Concentrated.

As in the case of an infantry division, it would be necessary to provide motor lorries fitted with water tanks to increase the supply to the troops to 1 gal. a head. Three 3-ton lorries, each carrying 600 gal., are proposed.

Cavalry Corps Troops.

The strength of these formations varies. Two motor water tank cars would suffice for requirements in any situation.

Army Troops.

It may be assumed that no additional transport would be required for these troops on the march, as they would normally be in rear of the corps. A proportion of the units would, however, be interspersed with corps and divisional troops during concentration, and it is proposed to make allowance for 5,000 men, providing one motor water tank car for headquarters, two equipments on lorries for clarifying and sterilizing water, one for removing poisons, and five motor lorries fitted with water tanks.

Organization.

It is proposed that the vehicles (other than regimental water carts) and personnel, including medical personnel, shall constitute water-sections of the supply columns of the formations to which they are allotted.

Barge Equipment.

There are now under supply five barges fitted with water purifying plant, with output capacity each of 40,000 gal. daily. Also 24 water tank barges each with storage capacity of 13,500 gal.

It is proposed that these barges and the personnel attached to them—R.E. and R.A.M.C.—should form part of the Inland Water Transport Establishment under the Director of Railway Transport.

It is not possible to estimate the extent to which troops will be served from these barges. Many factors are indeterminate, namely, the distance of troops from rivers or canals, obstructions to navigation, etc. There is no doubt, however, that for all troops in reserve formations, and frequently for troops concentrated, they will constitute valuable sources of supply of drinking water.

Supply of Purified Water to Animals.

The committee have not contemplated the possibility of making provision for the purification and conveyance of water required for animals, in view of the enormous amount of transport which would be necessary. Although the enemy might destroy or poison the supplies in certain localities, universal destruction or poisoning throughout a large area seems to be impossible. In case of emergency animals could be taken considerable distances to water. Moreover, animals can obtain water from hastily dug shallow wells, small streams, etc., which would not be suitable for human consumption.

APPENDIX D.

DIRECTIONS FOR THE USE OF LIME IN CLARIFYING WASTE WATER.

1.—*Memorandum on the Use of Chloride of Lime for the Clarification of Waste Water from Laundries, Bath-houses, and Kitchens.*

The ultimate disposal of waste water from kitchens, laundries, ablution rooms and bath houses by means of soakage pits, which has been the method generally adopted in the Field Force up to the present time, has frequently been attended with certain difficulties. It has been found that, with the varying amount of greasy matter or soap in the water, satisfactory soakage is difficult to obtain and the working arrangements frequently break down. The reason for this failure is that the fatty matter rapidly coats the bottom and sides of the soakage pits, soon rendering them impermeable, so that nuisance results. In the same way broad irrigation is apt to fail. In other cases the presence of an impermeable clay soil prevents even an attempt at treatment by either irrigation or soakage, and necessitates discharge into a ditch or stream. An effluent of this kind cannot be discharged untreated into a stream without causing serious nuisance. When treating soapy or greasy water it is obviously necessary, therefore, to produce an effluent containing a minimum of fatty material, whatever the ultimate disposal of that effluent may be.

A satisfactory effluent, whether for disposal by soakage or for discharge into a stream, can always be obtained by the use of chloride of lime, which is cheap and readily obtainable. The addition of chloride of lime to even the most heavily grease-charged water from either cook-houses or laundries causes the grease to separate rapidly and rise as thick scum to the surface, leaving a clear and purified water below. The chloride of lime should be added and stirred in the greasy water until oxidation is complete, as shown by the bleaching of the suspended matter. The grease rapidly flocculates and rises to the surface as thick scum. It can then readily be removed and may be burnt in the destructor or otherwise disposed of.

It has been found by experiment that from 0·3 to 1 per cent. of bleaching powder is required to clarify completely the majority of waste waters. Cresol should not be added to waste water intended for treatment by this process, as its presence interferes with the formation of the scum.

The clarified and purified water being charged with chlorine is sterile, and can be used for washing floors or cleaning latrine pails. When such an effluent is discharged over land or into streams the chlorine rapidly disappears, being used up in the oxidation of organic matter with which it comes in contact.

In order to carry out the process two tanks are required, in which the bleaching powder is added to the waste water, sufficient time being allowed for the scum to collect and form at the surface. Provision is made for drawing

off the clarified residual water below the scum and for passing it through a filter composed of sand alone, or of brick rubble, shingle and a surface layer of sand. It has been found that upward filtration succeeds best; and by this means a perfectly clear effluent, smelling of chlorine, can be obtained without difficulty. The filtration area required is comparatively small and should present no difficulty in construction.

Details of different Types of Plant which worked successfully.

A. Plant for disposal of waste water from kitchens.—Sullage water is treated with the chloride of lime in barrels, tubs or similar vessels and well mixed. The clarified effluent is drawn off from below by means of taps inserted near the bottom of the vessels into a common channel whence it passes to a small filter. Filtration takes place from below upwards, and the resulting effluent is bright and clear. The scum formed during the process can then be removed and burnt in the destructor.

The first practical test was carried out at No. 14 Stationary Hospital, Boulogne, by Captain Whitehead. It was then tried with success on a larger scale at the laundry of the 50th Division at Westoutre. Wherever tried, the system seems to have been a success, rendering the water clear and sterile, but, unfortunately, the question of expense and a shortage of bleaching powder put an end to its wider adoption.

B. Plant suitable for treatment of laundry effluent.—The following details of construction apply to a plant adapted to treating 3,000 gallons a day :—

The plant comprises two treatment tanks (each capable of holding a day's effluent) and a filter bed, with the necessary connecting pipes and valves.

The dimensions of each of the *treatment tanks* are 20 ft. by 12 ft. by 4 ft. 6 in.; the dimensions of the filter are 10 ft. by 8 ft. by 3 ft.

Tanks and filter may be constructed of any suitable material. Any gross solid matter is screened off by a ½-in. grid placed at the inlet of the treatment tank. Communication between each tank and the filter is by means of a 2-in. pipe, fitted with a valve or stopcock, let in one foot above the floor of the tank and discharging at the bottom of the 3-ft. filter bed.

Filter bed.—3-in. agricultural pipes are laid in the floor of the filter in such a way as to ensure an even distribution of the tank effluent; above these are laid in succession layers of broken brick, clinker, coarse cinders, fine cinders and finally a 4-in. layer of sand.

The outlet from the filter bed being 12 in. above the outlet from the treatment tank, a residuum of waste water with the collected scum is retained in the latter.

Method of working.—When one tank has been filled, the waste water flow is turned into the second tank.

The requisite amount of bleaching powder is then added to the contents of the first tank, mixed thoroughly, and the whole allowed to stand for a few hours, although a perfectly clear effluent may sometimes be obtained in a shorter period.

A little experience will indicate the exact amount of bleaching powder required to produce a satisfactory effluent in each particular case.

The effluent from the treatment tank is then passed into the filter bed, the rate of flow being governed by the valve fitted to the tank outlet.

The scum in the treatment tank consolidates, and is removed when the tank has again been filled and before the addition of a fresh quantity of bleaching powder.

A plant of the above description has proved capable of dealing effectually with the effluent from a large field laundry, one pound of bleaching powder per 26 gallons of waste water giving a perfectly clear and purified filter effluent. The amount of deposit that collects is small and it has been found that the treatment tanks have seldom to be cleaned out.

Much smaller plants on similar lines may be constructed for use in connection with bath-houses and ablution benches.

The advantages of the process are :—

(1) That it is suitable for both large and small units and for dealing with either soapy or greasy water.
(2) Clarification is complete ; the resulting effluent is practically free from suspended matter and grease, is sterile and can be disposed of in any pervious soil or discharged directly into a stream.
(3) The effluent being chlorinated is never objectionable.
(4) The plant required is simple.
(5) The necessary material is inexpensive and easily obtained.
(6) Little or no labour is required in working the plant.
(7) The scum formed can be removed and efficiently disposed of by burning, whilst the chlorinated effluent can be utilized in several ways.

2.—*Directions for ascertaining the Amount of Chloride of Lime required for the Treatment of Sullage Water.*

(1) Prepare a test emulsion of ½ oz. or seven levelled scoopfuls of bleaching powder in ½ pint of water. The bleaching powder should be made into a smooth paste with a small portion of the water before the full quantity of water is added. This forms a 5 per cent. solution.

(2) To a quart of the sullage water add one spoonful of test emulsion, stir well, and filter through a filter cloth or a small sand-filter in a tin box. If not clear return the filtrate to the original quart vessel and add another spoonful of test emulsion. Filter again if not clear, repeat with a third spoonful, and so on if necessary. The sand-filter should be washed after use.

(3) One spoonful in test corresponds to 2 oz. of bleaching powder per 100 gal. of sullage water.

(4) The bleaching powder must be made into an emulsion with water before being added to the sullage water. It must not be added in solid form. (The spoon used for the measurement of bleaching powder in the official water-sterilization test case will hold 3 c.c. of liquid or 2 gm. of bleaching powder.)

3.—*Use of Slaked Lime for the Clarification of Sullage Water.*

The soapy water runs from the bath-house into a mixing tank. Slaked lime is placed in this tank and thoroughly mixed by means of a windmill mixer constructed from a couple of old bicycle wheels and a hop-pole. When the wind fails the mixing must be done by hand, but this is hard work. The lime throws down the soap as insoluble calcium stearates, bringing down at the same time all the dirt and impurities. The effluent runs up and down through three settling tanks placed all on the same level. These are built of brick, with concrete floors. The partitions are removable wooden frames with canvas centres. The three settling tanks are respectively 3 ft., 4 ft. and 5 ft. wide. This gradual widening of the tanks tends to retard the flow of the stream, thereby assisting precipitation. All the calcium stearates will be found to have settled down in the first two tanks. The third tank is used for precipitating the lime and removing the soapy oils. This is effected by means of washing soda, which is run into the tank from a drum containing a saturated solution of sodium carbonate. This precipitates the calcium salts—chiefly hydroxides—as insoluble calcium carbonate, which immediately falls to the bottom of the tank. In addition to this, the sodium carbonate causes the soluble oils from the soap to separate out. These oils, which give the water an odour of soap, float on the surface, and are absorbed by means of canvas or sacking nailed on to wooden frames. The canvas is changed daily. From this third settling tank the water flows into a charcoal filter containing 4 in. of powdered charcoal between two layers of sacking. Through this filter

it runs into a bricked, concreted well, and is pumped thence into the elevated tank by the petrol pump. Thin canvas screens, stretched on strong wire frames, are placed in the channels connecting the precipitating tanks. These hold back the scum of lime which separates out on the water cooling. The first precipitation tank is cleaned out every three or four days and the mixing tank daily. The sludge is buried. The sludge, which is odourless except for a slight smell of lime, does not show any tendency to decompose. The water, after treatment, is quite clear, free from dirt, soap, lime and soapy oils; and, furthermore, it gives a good lather with soap on being used again. The same water may be treated by this method and used an indefinite number of times. The only fresh water required is that to replace the loss caused by cleaning the tanks. No great quantity, however, is requisite, since most of the contents of each tank can be pumped into the succeeding one until the sediment is reached.

In experimenting with the working model in order to ascertain the size of the charcoal filter required for dealing with 4,000 gal. a day, it was shown that the rate of flow through the filter varied directly as the height of the superimposed column of water. A charcoal filter 6 ft. square was found to be adequate. This filter consists of a wooden frame 6 ft. square and 18 in. high, lined with zinc. The floor, made of zinc, is perforated with holes of medium size and is covered with sacking on which a layer of powdered charcoal 4 in. thick is spread. This is covered with sacking which is changed and washed daily.

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